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Livestock production in central Mali: Long-term studies on cattle and small ruminants in the agropastoral system

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ABSTRACT

ILCA has been conducting a long-term study on livestock production in central Mali since the beginning of 1976. This report presents results based on data collected over a 6-year period from 1978 to mid-1984. In Part I the livestock production systems in the zone, management practices and herd and flock demography are described. Cattle and small ruminant productivity is discussed in detail in Parts II and III and recommendations based on the results of the studies are given in Part IV.

KEY WORDS

/Sahel//Mali//cattle//sheep//goats//livestock production systems//productivity//livestock management/ /herds//reproduction//growth//mortality/

RESUME

En 1976, le CIPEA a entrepris une étude à long terme sur la production animale dans le centre du Mali. L'analyse des données recueillies de 1978 à 1984 est présentée dans le présent rapport, qui comprend quatre parties. La première est consacrée à une description des systèmes d'élevage, de la conduite des troupeaux et de la démographie animale. Les deuxième et troisième chapitres traitent des divers aspects de la productivité des bovins et des petits ruminants, et le quatrième présente des recommandations fondées sur les résultats de l'étude.

MOTS CLES

/Sahel//Mali//bovin//mouton//chèvre//système d'élevage//productivité//exploitation du bétail//troupeau// reproductivité//croissance//mortalité/

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PREFACE

In the past, little attention was given to traditional systems of livestock production. Indigenous breeds of livestock were considered to have low genetic potential and to contribute only marginally to agricultural production. Moreover, with very few exceptions, the term 'livestock' was almost invariably used as a synonym for cattle: goats and sheep, if considered at all, were regarded as mere harbingers of degradation and drought.

In recent years, some of the old attitudes to traditional livestock production have changed but there is still very little information available on the productivity of local animal breeds under traditional management. This report presents the findings of research work carried out by the International Livestock Centre for Africa (ILCA) on cattle and small ruminant production in central Mali.

The author of this report, who was the Senior Animal Scientist and later Team Leader of ILCA's research programme in Mali, is now Head of the Small Ruminant and Camel Group at ILCA's headquarters in Addis Ababa, Ethiopia.

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Data were collected for this report over a period of more than 6 years. I could not possibly thank individually all the staff of ILCA's programme in Mali who were involved in the study but I am, needless to say, grateful to each and everyone for their contributions.

Issa Haidara and Aba Mariko were largely responsible for collecting the field data, and latterly they were supervised in this by Adama Traoré. Analyses were carried out in conjunction with ILCA's Computer Unit in Addis Ababa and Robin Sayers, Jeff Durkin and Darrell Light provided invaluable assistance and advice. Engda Girma cleaned and corrected the data.

Mary Wilson suffered much throughout in addition to typing many drafts over the years. Azeb Melaku, assisted by Abeba Zenebe, struggled with appalling calligraphy, oversized tables and yet further drafts while remaining both undismayed and cheerful.

Ilse Alipui is thanked for editorial assistance and the staff of the ILCA Publications Division for designing, typesetting and printing this report.

SUMMARY

This study provides data on livestock production systems in the West African Sahel with special reference to Mali. Management practices are described and details of demography in relation to herd and flock function are provided.

Data on cattle productivity were collected during a 6-year study of nine herds. Average age at first calving was 49.5 months and mean parturition interval was 22 months. Calving was highly seasonal and correlated with rainfall at 9 and 10 months previously. Total lifetime production of young was about three calves per breeding cow. Growth was slow and mature weights were not reached until 5 years of age. Weight losses occurred each year during the dry season even in young, growing stock. Over the 6-year study period, mature weights of oxen declined by about 100 kg and those of cows by about 30 kg, both being correlated with a reduction in annual rainfall. Abortions totalled 3.3% of all parturitions and total deaths to 4 years of age were 31.6%. Adult mortality was about 5% and offtake about 8.4%. The three productivity indices calculated (weight of calf produced per breeding cow per year, per kg breeding cow per year and per kg metabolic weight of breeding cow per year) were 34.4 kg, 0.16 kg and 0.70 kg.

Data on small ruminants were collected from 40 flocks. Average age at first parturition was 15.9 months, the mean kidding interval for goats was 9.6 months and for sheep 8.6 months, while litter sizes were 1.19 and 1.04 for the two species respectively. The average numbers of parturitions for breeding females present in the flocks were 2.2 for goats and 1.8 for ewes. Growth was rapid and continued uninterruptedly to 3 years of age with much less marked seasonal variations than in cattle. Abortions in goats and sheep were 12.6% and 5.1% respectively while total preweaning mortalities for the two species were 34.4% and 23.4%. At 4 years of age, only 38% of all goats and 30% of all sheep born were still in the flocks. The productivity indices for goats were 14.6 kg, 0.494 kg and 1.23 kg and those calculated for sheep were 28.4 kg, 0.867 kg and 2.22 kg.

SYNTHESE

Ce rapport est consacré aux résultats d'une étude sur les systèmes d'élevage sahéliens menée en Afrique occidentale, au Mali. Les modes de conduite du troupeau, les variables démographiques et leurs liens avec la finalité de l'élevage y sont présentés.

La productivité bovine a été calculée sur un échantillon de neuf troupeaux suivis pendant six ans. L'âge moyen au premier vêlage est de 49,5 mois et l'intervalle moyen entre mises bas de 22 mois. Les vêlages sont groupés et analysés en rapport avec la pluviométrie observée neuf à dix mois auparavant. Les observations portent en moyenne sur trois veaux par vache reproductrice présente dans le troupeau. Les gains de poids sont faibles et le poids adulte n'est pas atteint avant l'âge de 5 ans. Des pertes de poids interviennent chaque année pendant la saison sèche, même chez les jeunes en croissance. Le poids adulte des mâles a diminué d'environ 100 kg pendant l'étude et celui des femelles de 30 kg. Ce phénomène est lié à la diminution de la pluviométrie. Le taux d'avortement est de 3,3% et le taux de mortalité cumulé jusqu'à 4 ans est de 31,6%. La mortalité des adultes s'élève à 5,0% et le taux d'exploitation est évalué à 8,4%. Les indices de productivité (poids de veau produit par reproductrice et par an, par kg de vache adulte par an et par kg de poids métabolique de reproductrice par an) sont respectivement de 34,4 kg, 0,16 kg et 0,70 kg.

Chez les petits ruminants, la productivité a été calculée sur un échantillon de près de 40 troupeaux. L'âge moyen à la première mise bas est de 15,9 mois et l'intervalle moyen entre mises bas de 9,6 mois chez la chèvre et de 8,6 mois chez la brebis. La taille moyenne de la portée est de 1,19 chez les caprins et de 1,04 chez les ovins. Le nombre de naissances par reproductrice présente dans le troupeau est de 2,2 pour les chèvres et de 1,8 pour les brebis. La croissance est rapide et continue jusqu'à 3 ans et les pertes pondérales de saison sèche sont moins importantes que chez les bovins. Le taux d'avortement atteint 12,6% chez les caprins et 5,1% chez les ovins et la mortalité au sevrage 34,4% et 23,4%. Le taux de survie des animaux de 4 ans est de 38% chez les caprins et 30% chez les ovins. Les indices de productivité atteignent 14,6 kg, 0,494 kg et 1,23 kg chez les caprins et 28,4 kg, 0,867 kg et 2,22 kg chez les ovins.

PART ONE

GENERAL BACKGROUND

1. INTRODUCTION

GENERAL

Almost all livestock output in developing countries results from animals kept in the traditional sector. However, attempts to improve output are based almost exclusively on transferring technologies developed under experimental station conditions. While local types of animals are often used on these stations, usually little is known of the actual performance 'across the fence' under traditional systems of management.

In an attempt to overcome this deficit of information, the International Livestock Centre for Africa (ILCA) has embarked on a series of systems studies in various ecological zones. Central Mali is part of the Sahel ecoclimatic zone where ILCA has been conducting a long-term study since the beginning of 1976. The results presented in this report are from data collected over a period of more than 6 years from 1978 to mid-1984.

In 1981 the livestock population of Mali was estimated to include 5.1 million cattle, 6.3 million sheep, 7 million goats and 173 000 camels (FAO, 1981). These figures were similar to those reported before the 1968–1973 Sahelian drought. In terms of numbers, cattle are thus very important in the Malian livestock economy. They represent more than 70% of the total liveweight of all domestic ruminants, and therefore are the major consumers of the fodder resources available.

CATTLE TYPES AND DISTRIBUTION

Most cattle in Mali are in the Sahelian and Sahelo-Sudanian zones in the central belt of the country between about 12° and 17° latitude. Annual rainfall in this area varies from 100 mm in the north to 1200 mm in the south. North of 17° there is virtually no permanent livestock population. To the south, livestock management is complicated by the presence of the tsetse fly, although there are some *Bos taurus* cattle of the N'Dama and West African Shorthorn types in this zone, and it is possible to maintain reasonably high levels of production under chemical prophylaxis (Logan et al, 1984).

The predominant breed of cattle in central Mali is the Sudanese Fulani (Mason, 1969). A male animal of this breed is shown in Figure 1. In the extreme west near the Senegal border, some Gobra are present; Maure cattle occur seasonally along the Mauritanian frontier and the Azaouak breed belonging to the Tuareg is found in the east. Figure 2 shows the principal features of central Mali and the distribution of the main cattle types.

SMALL RUMINANT TYPES AND DISTRIBUTION

Based on the demographic structure of the livestock population and the mean population weight, goats and sheep account for 22.2% of the total domestic ruminant biomass in central Mali. They are thus an important resource not only in the livestock economy but also in the total economy of the country. Their ability to produce meat, milk and other products even under the harsh environmental conditions of the semi-arid zone and at periods of the year when cattle are not producing makes them very important in the livelihood of traditional pastoralists and agropastoralists.

In the study area, direct subsistence is a major objective of small ruminant husbandry. Meat, milk and fibre all contribute to this subsistence while surplus males are sold off for cash.

In central Mali the majority of goats are of the West African Sahel type (Mason, 1969). In some urban areas and in the south small numbers of the dwarf type of goat, common in the more heavily wooded and forested humid zones, are found (Figure 3). Although attempts are sometimes made to classify the Sahel goats (Figure 4) into breeds, the difference between them is negligible and there seems to be no justification for this practice.

Figure 1. *A Sudanese Fulani stud bull at the Station du Sahel, Niono.*

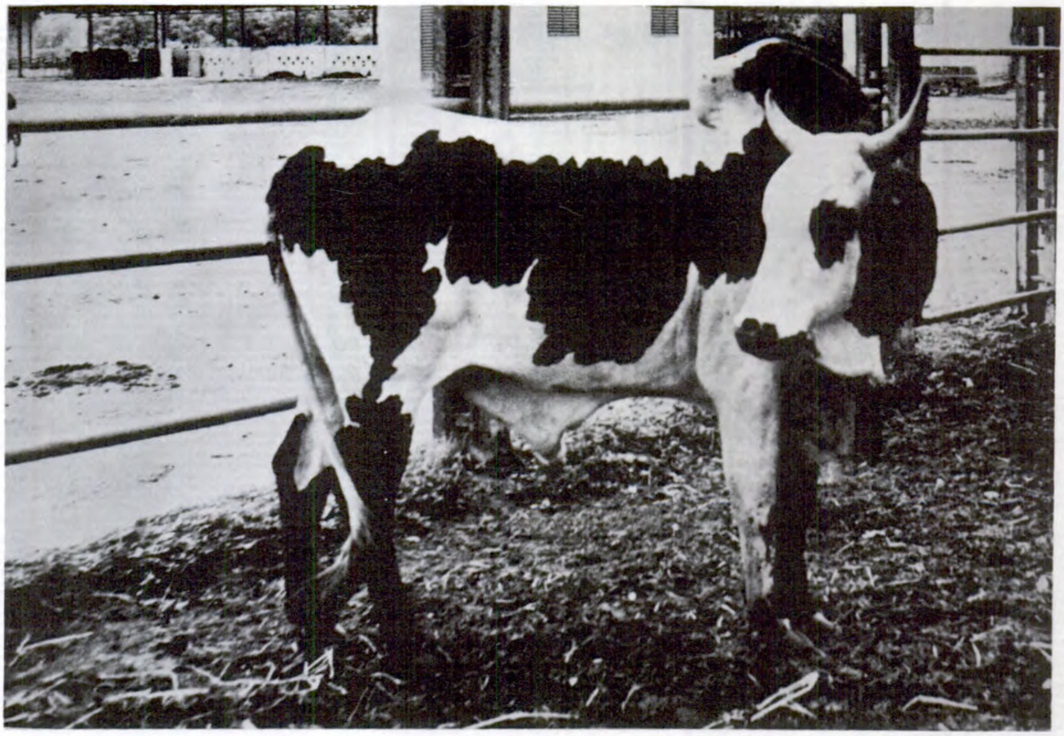


Figure 2. *Distribution of cattle types in central Mali.*

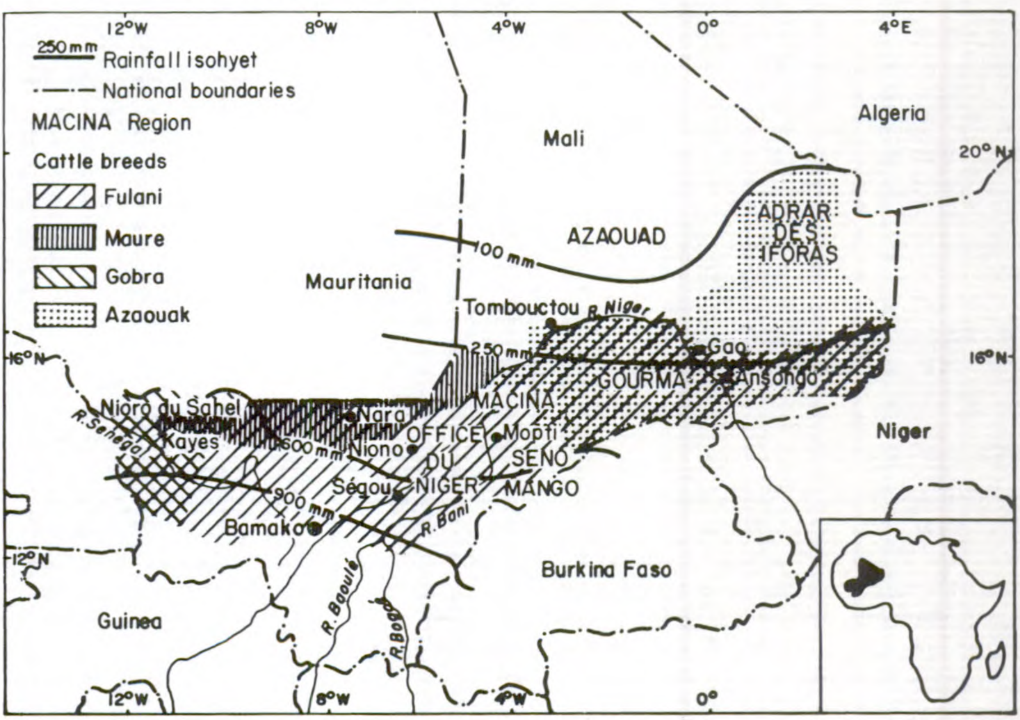


Figure 3. *A goat of the West African Dwarf type.*

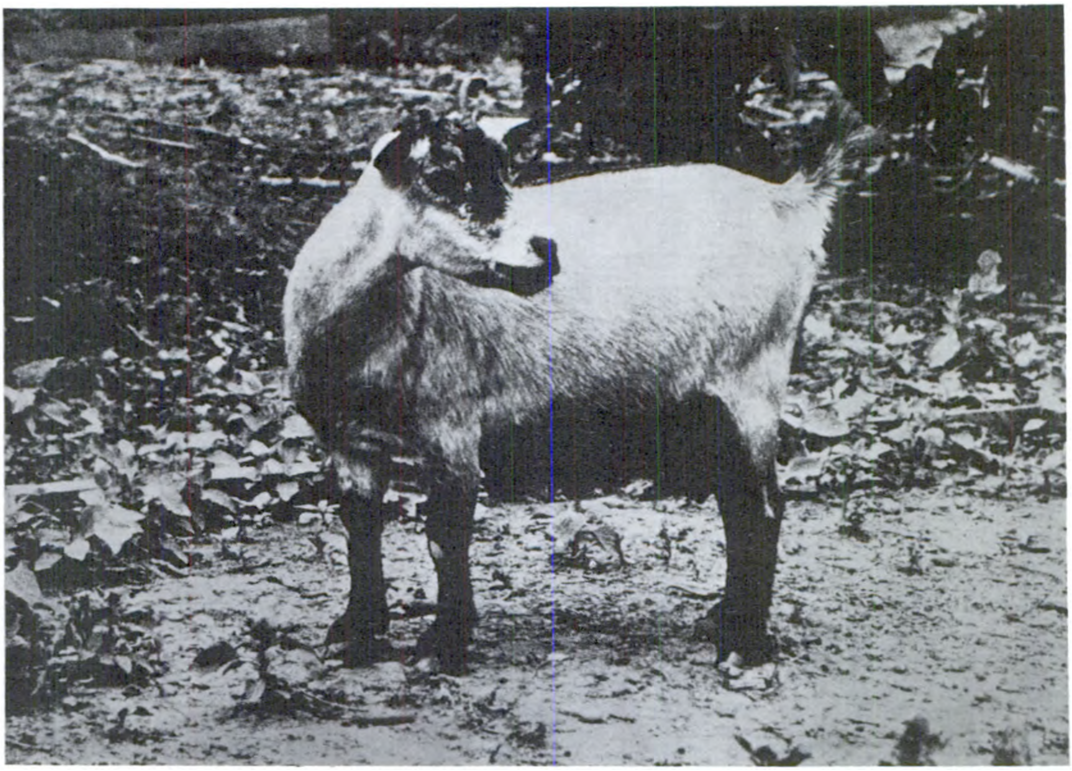
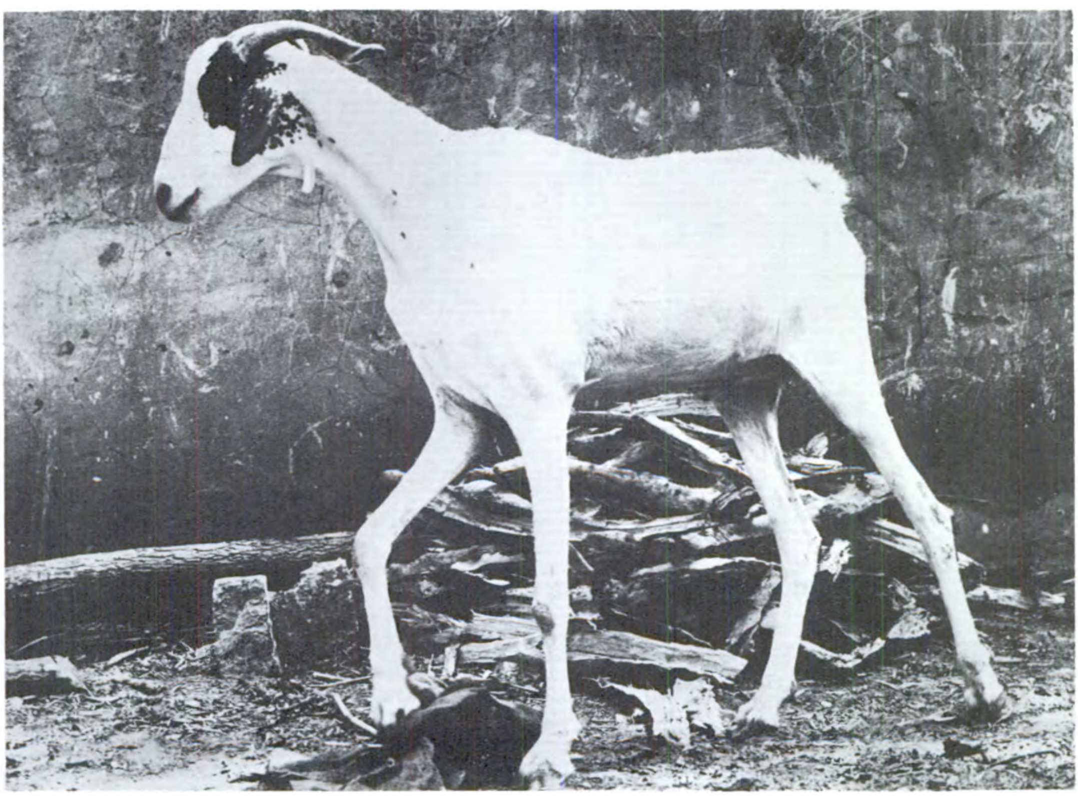


Figure 4. *A goat of the West African Long-legged type.*



The variation in sheep is greater, and there are three distinct types of the West African Long-legged sheep (Mason, 1969). These are:

- The Toronké variety of the Fulani breed (Figure 5), which is owned by Fulani transhumants who migrate seasonally over most of central Mali. Animals of this variety (and its crosses with the West African Dwarf) are also owned by most of the agropastoral sedentary farmers of the region. This variety is the one used in the long-term studies described in this report.
- The long-haired Black Maure (Figure 6), which is found in the dry season along the Mauritania/Mali border and southwards for distances of up to 100 km. The flocks are kept as pure as possible so that the hair used in tent-making will be of good quality. As most Moors keep flocks of the short-haired White Maure or Tuabir sheep in addition to the black breed, some crossing and dilution does occur.
- The white, pied or fawn Tuareg breed (Figure 7), which is kept mainly by nomadic or transhumant Tuaregs. In central Mali, the breed is found mainly in the Gourma region but it also extends north of the Niger river to the Adrar des Iforas and eastwards into the Niger Republic.

In addition to these hair sheep, one of the few true wooled breeds of Africa also occurs in central Mali. This is the Macina breed (Figure 8),

Figure 5. *Toronké variety of the Fulani sheep at Niono market.*

Figure 6. *Black Maure ram in a harvested field.*

Figure 7. *A ram of the Tuareg type in central Mali.*

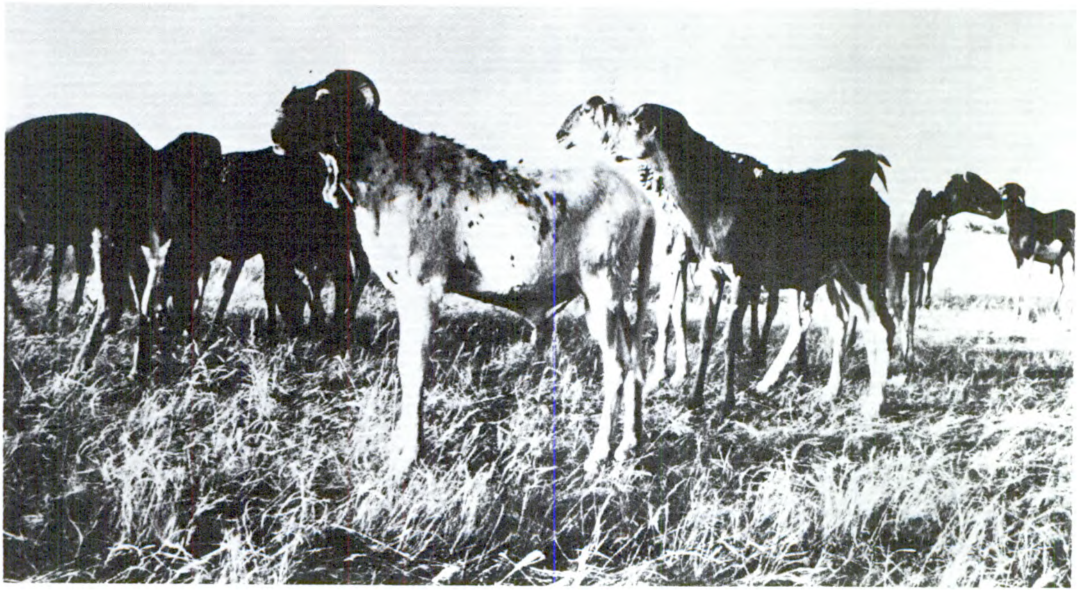
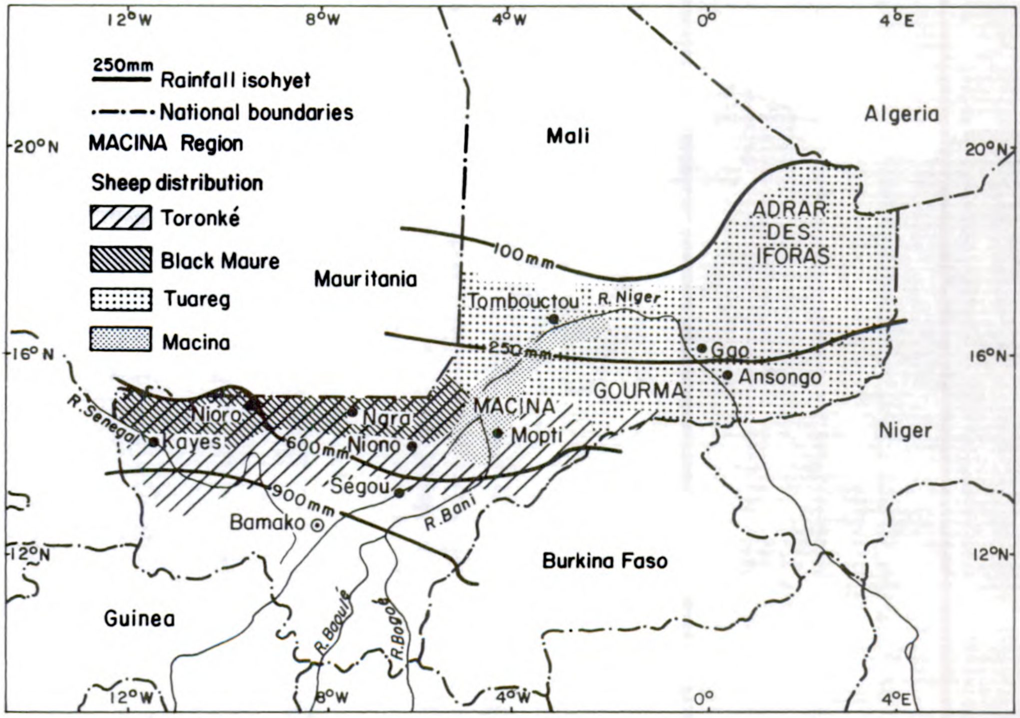


Figure 8. *Macina wool sheep.*

which is kept mainly for its coarse wool which is used in local blanket and garment manufacture. The owners are almost all agropastoral Fulani who also cultivate rice. The sheep is confined largely to the inundation zone of the River Niger, but short-distance migration takes place each year to avoid the seasonal floods.

The distribution of these types of sheep in central Mali and adjoining areas is shown in Figure 9.

Figure 9. *Distribution of the main sheep types in central Mali.*



2. THE STUDY AREA

LOCATION

Central Mali, defined as the area of the country between latitudes 12° and 16° N, was the area of study covered by this report. Most of the detailed work was carried out using Niono (14°15' N, 6°0' W) as the centre of operations. Niono is the location of the Station d'Elevage et de Recherches Zootechniques du Sahel, one of the research stations operated by the Livestock Division of the Malian National Institute for Research in Livestock Production, Forestry and Hydrobiology. This station was used as a base by the ILCA research team, and ILCA scientists collaborated with the government staff throughout the period of the study. Most of ILCA's field work was carried out off-station among traditional livestock producers. Most herds studied were within a 40-km radius from Niono except for three situated at Ségou, some 120 km to the south. Additional specific studies were undertaken for varying periods of time throughout central Mali.

CLIMATE

Central Mali has a Sahelian-type climate characterised by highly seasonal, unimodal rainfall falling mainly in the period from June to September. Precipitation is highest in late July or early August. The long-term (1930–1976) average annual rainfall at Niono is about 550 mm, but since the start of the notorious Sahel drought of 1968 to 1973, the rainfall has been considerably less. During the 1978–1983 study period the annual average rainfall was less than 400 mm; details (averaged for five stations within 40 km of Niono) are given in Table 1. Occasional minor falls of rain in months other than those shown in the table are ignored, as this rain does not contribute to primary production.

Mean temperatures in the area vary from a high of 31°C in May and June to a low of 23°C in January. Humidity is highest in June and throughout the rainy period of July to September; it is lowest in February and early March. A climatic diagram for Niono, which can be considered typical of much of the central Mali area, is given in Figure 10. Fuller details of the rainfall regime of the area can be found in Wilson et al (1983).

VEGETATION

In the south of the study area, where annual rainfall is generally in excess of 800 mm, the vegetation is a typical north-Sudanian deciduous woodland with many Combretaceae (*Terminalia acroptera*, *T. avicennioides*, *Combretum ghazalense*) and Leguminosae in the tree layer. Tree density is of the order of 150–3000 per hectare with a canopy cover of 20 to 50%. A feature of this zone is the large number of economically useful species retained within the agro-sylvo-pastoral system, such as *Parkia biglobosa* (the locust bean tree), *Butyrospermum parkii* (the shea-butter nut or *karité* tree) and *Adansonia digitata* (the baobab tree). The last is an introduction in this zone and is valued for its bark (for string-making), for its leaves (dried and used as a vegetable) and for a variety of other uses. The herbaceous layer is composed of medium to tall perennial and long-cycle annual grasses, including *Sporobolus pyramidalis*, *Andropogon gayanus*, *A. pseudapricus*, *Diheteropogon hagerupii* and *Loudetia togoensis*. Primary production of the herbaceous layer is of the order of 3.5 t DM/ha.

In the central zone of 300 to 600 mm annual rainfall, some Combretaceae remain in the tree layer but there is, as one moves north, a greater dominance of thorny Leguminosae, including *Pterocarpus lucens*, *Acacia seyal*, *A. laeta* and

Table 1. *Rainfall for Niono, 1977–1983.*

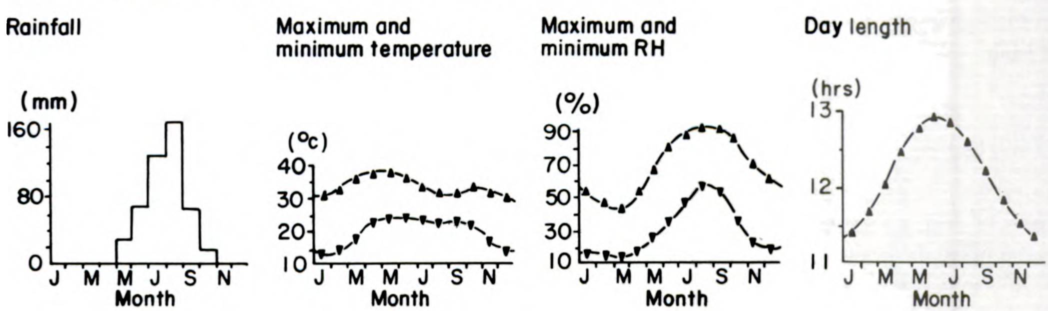
Month	Rainfall (mm)							Mean
	1977	1978	1979	1980	1981	1982	1983	
May	21.8	3.6	28.7	7.3	31.0	9.8	0.0	14.6
June	40.3	32.4	68.7	40.4	40.8	41.4	2.3	38.0
July	77.5	162.6	78.9	96.1	107.6	60.6	45.7	89.9
August	177.3	149.2	141.4	122.2	171.9	179.7	102.2	149.1
September	67.2	90.1	85.3	66.5	13.0	46.0	15.1	54.7
October	0.0	10.8	7.9	9.7	0.0	0.0	0.0	4.1
Total	384.1	448.7	410.9	342.2	364.3	337.5	165.3	351.9

Dichrostachys cinerea. *Sclerocarya birraca* and *Anogeissus leiocarpus* are important in the southern part of this central zone. On sandy terraces, *Acacia albida* is a conspicuous component of the woody flora and is much valued as a provider of dry-season forage of high protein content. The number of trees per hectare varies from 500 to 2000, with a canopy cover of 5 to 15% in the north. Grasses are mainly annuals, including *Elionurus elegans*, *Schoenefeldia gracilis* and *Chloris prieurii*, with a maximum standing crop biomass (SCB) of 2500 kg DM/ha in the south and 1200 kg DM/ha in the north.

In the north-Sahelian zone where annual rainfall is below 300 mm, taller trees are replaced by shrubby growth, including many thorny species and some Euphorbiaceae. Typical species are *Grewia bicolor*, *Boscia senegalensis*, *Maerua crassifolia* and *Acacia tortilis*. The maximum number of trees per hectare is 500, with a canopy cover not exceeding 10%. The field layer is dominated by short-cycle annual grasses including *Eragrostis tremula*, *Cenchrus biflorus*, *Aristida mutabilis* and *Tragus bertheronianus*. One of the few perennials on dune sands is *Panicum turgidum*. The SCB of the field layer does not exceed 800 kg DM/ha.

In central Mali, the vegetation pattern is complicated by the complex geomorphology of the so-called 'dead' delta and the present inundation zone of the Niger river, also known as the 'live' delta. Fuller details of vegetative composition and primary productivity can be found in Wilson et al (1983).

Figure 10. *Climatic normals for the Niono area, 1930–1976.*



3. LIVESTOCK PRODUCTION SYSTEMS

LIVESTOCK IN THE SAHEL ZONE

As shown in Table 2, the Sahel proper (including the same ecological zone in the Sudân republic) has a total estimated livestock population of over 33 million tropical livestock units (TLU, these being the 'unité de bétail tropical' of francophone authors), each equivalent to 250 kg liveweight. This is over a quarter of the livestock population of tropical Africa (CIPEA, 1981), which suggests that the Sahel is an extremely important region in terms of animal production. Over the past 15 years, the Sahel, previously neglected, has been a focus of world attention, as the 1968–1973 drought clearly showed the vulnerability of this area and the pressing need to solve its development problems. In many parts of the Sahel, livestock are the only means of subsistence, since the extreme variability of the rainfall makes cropping very risky. Combining crop with animal production improves food security. In some areas of the Sahel, cropping would not be possible were it not for the presence of livestock which provide an alternative source of food for the human population when the periodic grain deficits caused by poor rainfall occur. Livestock in the Sahel therefore play a part which is not simply related to mere numbers.

Livestock distribution in the West African Sahel shows a high degree of diversity. In some parts, a clear congruence can be seen between areas of medium-to-high densities of livestock and areas of dense human populations (Figures 11 and 12). This is the case in western and central Senegal and, even more markedly, in the intensive agricultural zone of southern Niger, where intense population pressure and shortage of fallow land forces animals to move north during the cultivation season. However, this correlation does not occur in Burkina Faso or Mali, where there is a relatively high density of animals in the western part of the Niger inundation zone and low densities on the Dogon and Mossi plateaux, where farmers are too poor to invest in animals and do not use cattle for traction. A map of livestock numbers per rural inhabitant (Figure 13) indicates the extent to which the rural population is dependent on pastoral activities, clearly showing the importance of livestock in the north of the region as compared to the south (except for southern Niger and southern Senegal).

The important pastoral areas in Mali are found in the central and northern parts of the country, especially in the two administrative divisions of Nioro du Sahel and Nara (where pastures along the Mauritanian border are used by Moors), the northwest part of the Niger delta (where Fulani animals are grazed) and the Gourma-Rharous, Gao and Menaka divisions (which are part of the Tuareg pastoral zone). Other important pastoral areas are in Niger (notably the Wodabe and Tuareg areas in the west and centre of the country) and in the Dori region of northern Burkina Faso (where both Fulani and Tuareg herds are found).

LIVESTOCK PRODUCTION IN MALI

Ecological zones

Crop and animal production systems in Mali are influenced primarily by rainfall. The mean annual rainfall isohyets for Mali and the main ecological zones delineated by them are shown in Figure 14. However, the area flooded annually by the Niger river has its own characteristic vegetation and land use. On the basis of rainfall and annual flooding it is possible to define four broad ecological zones.

The arid zone. Dominated by pastoral production, this zone includes all land receiving less

Table 2. *Distribution of ruminant livestock by species in the Sahel countries.*

Country	Camels		Cattle		Sheep		Goats		Total TLU
	('000 head)	(TLU)[a]	('000 head)	(TLU)[a]	('000 head)	(TLU)[a]	('000 head)	(TLU)[a]	
Senegal	4	4	2 806	1 964	1 884	188	1 000	100	2 256
Mali	208	208	4 459	3 121	6 067	607	5 757	576	4 112
Burkina Faso	87	87	2 700	1 890	1 800	180	2 700	270	2 427
Niger	330	330	2 995	2 096	2 500	250	6 400	640	3 316
Chad	410	410	4 070	2 849	2 278	228	2 278	228	3 715
Sudan	2 500	2 500	17 300	12 110	17 200	1 720	12 200	1 220	17 550
Total head	3 529		34 330		31 729		30 335		33 776

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

Sources: FAO (1979); CIPEA (1981).

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

Figure 11. *Livestock densities in the Sahel countries.*

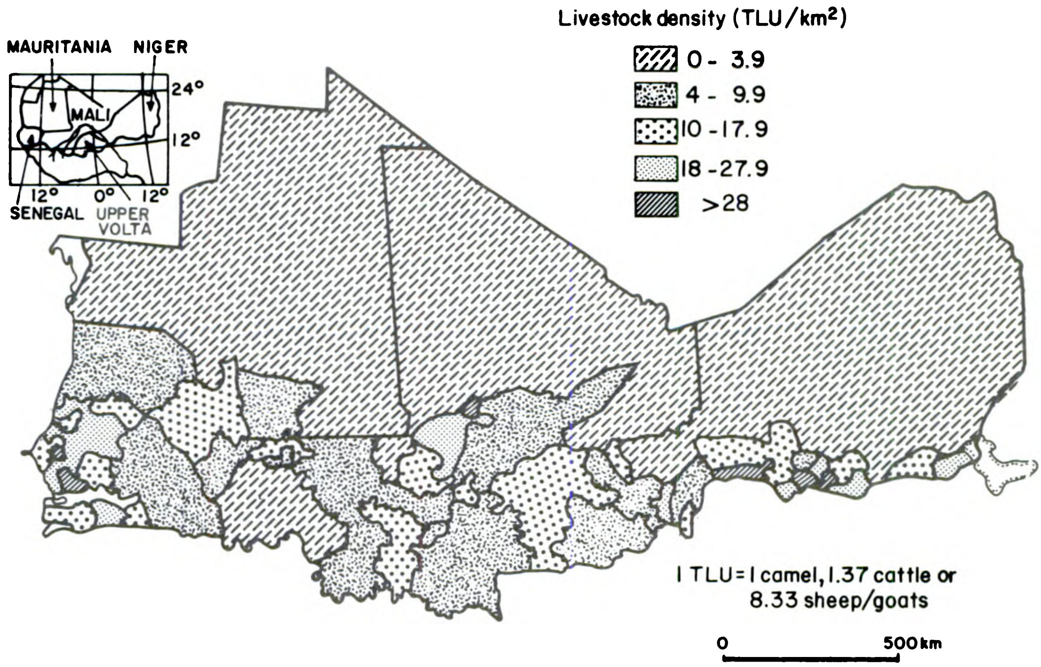
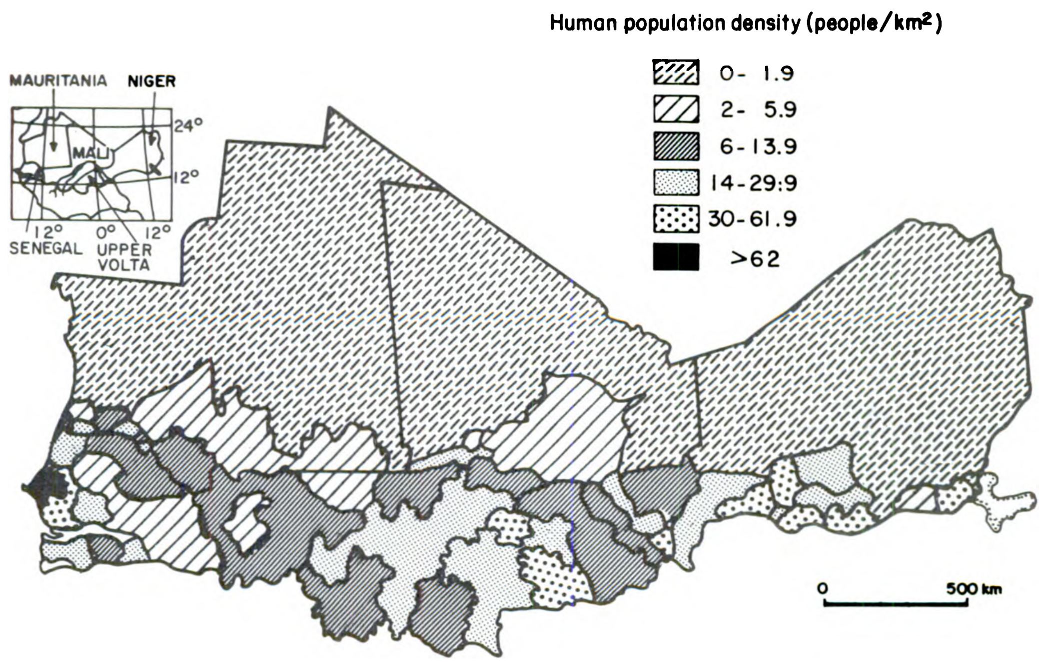


Figure 12. *Human population densities in the Sahel countries.*



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

The subhumid zone. Associated with high-potential rainfed crop production, this zone lies south of the 1000 mm isohyet, covering only the southern fringes of Mali. It includes the southern Sudanian vegetation belt. The higher and more reliable rainfall permits rainfed cultivation of cotton, while sorghum and to a lesser extent maize are the dominant food crops.

The inundation zone of the Niger river. Associated with floodplain grasslands and some farming, this natural region forms a fourth zone where vegetation is strongly influenced by the annual flood. Its extent is coincident with the distribution of Macina sheep (Figure 9). The zone includes the rich grasslands grazed by Fulani pastoralists, areas of traditional cropping, and areas of rice cultivation under semi-controlled irrigation.

Distribution of people and animals

Rural population densities in Mali are given in Figure 12. The pattern shows three main areas. The first is a large area of very sparse settlement (<6 people/km^2), roughly equivalent to the pastoral zone with its predominantly livestock-based economy (the 'pure' pastoral production system), but also including the hilly area in the southwest of the country, which is heavily infested with the tsetse fly. The second area has medium to dense settlement (>14 people/km^2) and includes: the Dogon Plateau and adjacent areas; Diré, a small district with an extensive irrigation potential resulting from the nearby course of the Niger; all the remaining irrigable areas of the floodplain; the Office du Niger, a controlled irrigation scheme owned and normally managed by the state; and the intensive rainfed agricultural areas of southeast Mali together with the area around Bamako. The remainder of the country constitutes the third area, which has moderate settlements (6–14 people/km^2).

Figure 11 shows the density of livestock per km^2 in TLU. For Mali, the livestock pattern indicates two main areas. The first has low animal density and lies in two different parts of the country: in the pastoral zone where large tracts of land are scarcely used because of lack of water, and in southwest Mali where tsetse flies restrict livestock production. Both correspond with areas of low human settlement. The second area is one of high animal density in the Niger floodplain, corresponding closely with a production system in which pastoralism is associated with irrigated cultivation. This pattern occurs to a lesser extent in the

Figure 13. *Numbers of TLU per rural inhabitant in the Sahel countries.*

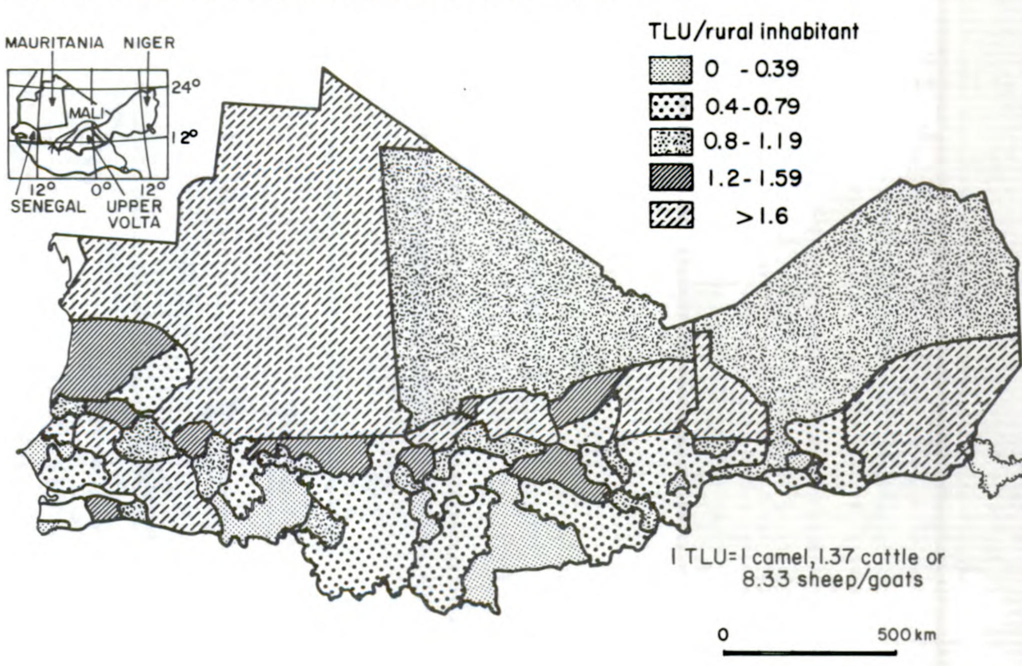
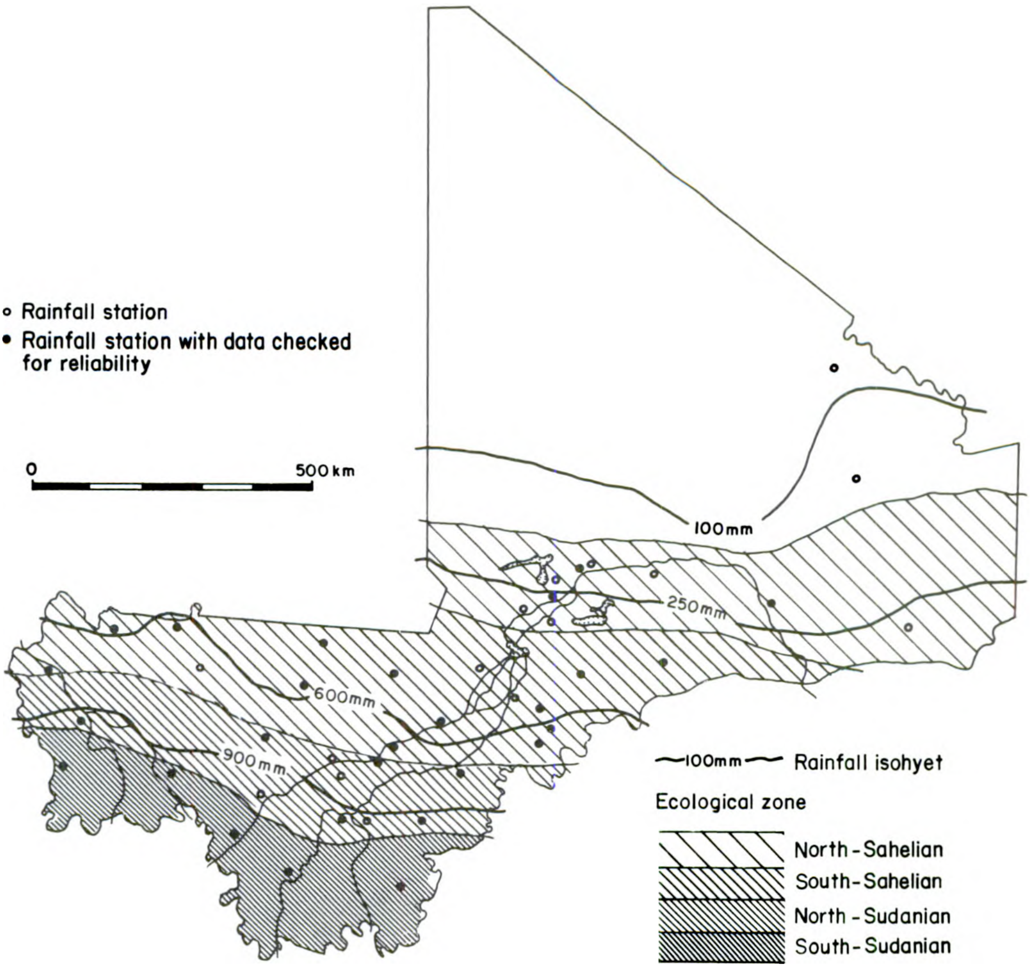


Figure 14. *Annual rainfall and ecological zones in Mali.*



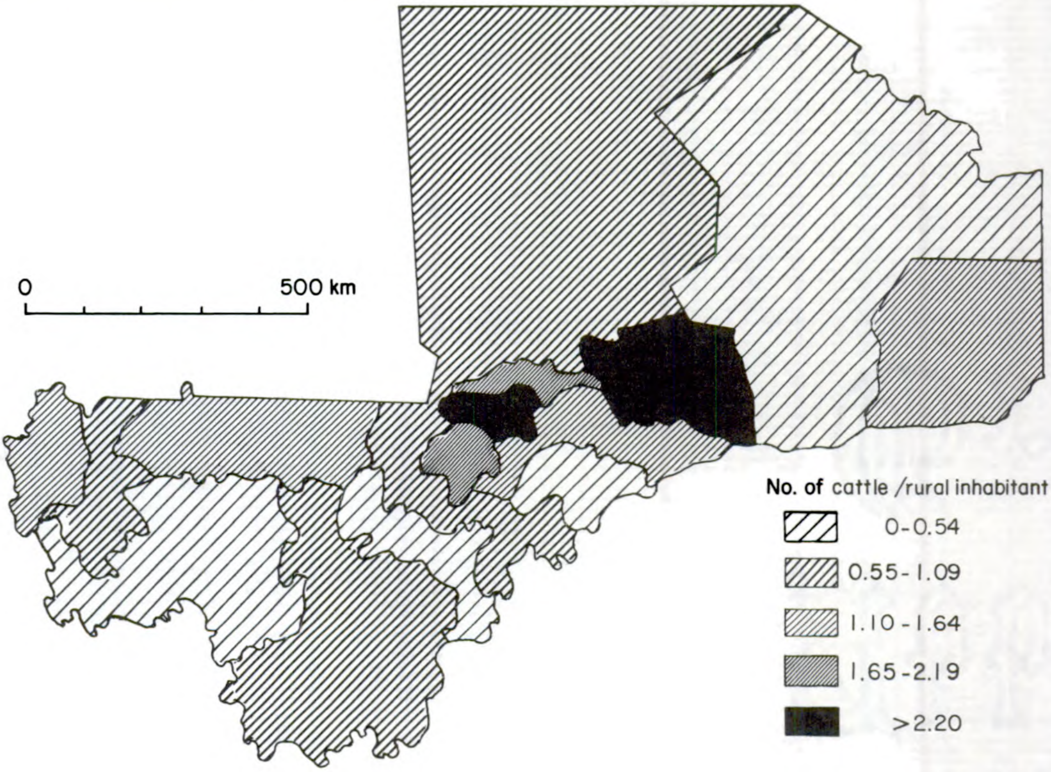
intensive rainfed agricultural areas of extreme southern Mali.

The number of TLU per rural inhabitant is shown in Figure 13, giving an impression of the dependence on livestock or the livestock-based wealth in different parts of the West African Sahel. In the case of Mali, the two highest density categories (i.e. >1.2 TLU/rural inhabitant) correspond closely with the northern pastoral zone and the Niger inundation zone, i.e. with the pure pastoral and floodplain-associated pastoral production systems. The area with the highest ratio of animals to people (4.4 TLU/rural inhabitant) is the Gourma-Rharous district in central Mali. Outside the northern pastoral and inundation zones, livestock numbers per rural inhabitant are much lower, especially in the sparsely inhabited southwestern parts of the country.

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

The areas of high cattle density (Figure 15), containing an average of more than one head of cattle per rural inhabitant, occur in a belt along the southern edge of the pastoral zone: in the Nioro du Sahel and Nara districts along the Mauritanian border; in the Niger floodplain; in the Gourma-Rharous district; and in the Menaka district in the east. This pattern corresponds with the production systems in which pastoralism is associated with either dryland or floodplain cultivation, as well as with the southern fringe of the 'pure' pastoral system.

Figure 15. *Number of cattle per rural inhabitant in Mali.*



The distribution of sheep and goats per rural inhabitant (Figure 16) is somewhat different. The three highest density areas, containing more than 2.2 sheep or goats per rural inhabitant, form a belt corresponding roughly with the pastoral zone and the 'pure' pastoral production system. Sheep and goats have a more northerly and easterly distribution than cattle, with the highest densities lying in the Gourma-Rharous, Gao, Bourem and Menaka districts. They are much less important in the rest of Mali, especially in the south. With the exception of Macina wool sheep, small ruminants are less numerous in most of the Niger floodplain which is first and foremost a cattle zone.

The estimated distribution of people and livestock by ecological zone in Mali (Table 3) shows that the rural population is concentrated mainly in the semi-arid zone which, although it covers only 16% of the country, contains 45% of its inhabitants. The subhumid zone to the south contains just over one quarter of Mali's rural population, while the arid zone and the Niger river inundation area contain another 15% each.

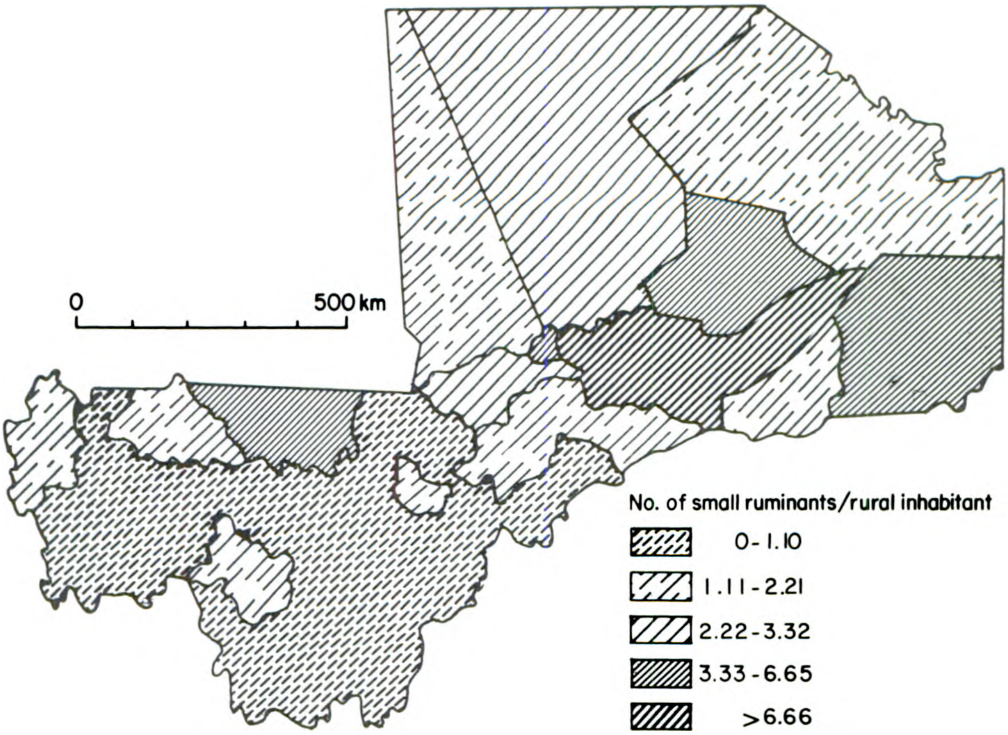
The arid or pastoral zone contains over 90% of Mali's camels and 43% of its sheep and goats, but only 21% of its cattle. However, it should be remembered that the cattle, sheep and goats from the Niger floodplain also use the rangelands of the pastoral zone for 6 months of the year, as do many cattle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

Table 3 highlights the importance of the semi-arid zone, which contains one third of Mali's cattle and nearly one third of its total TLU, although it is far smaller in area than the arid zone.

Production systems

Two main criteria have been used to define the animal production systems of Mali: the first is the degree of dependence on pastoral products for the gross revenue or food supply of the household or production unit; the second is the particular type of agriculture associated with the livestock system. Other criteria, such as the duration and distance of livestock movement, were considered as less important. While livestock movement may be an important aspect of an animal production system, it is contingent upon the system, often having the effect of diverting attention away from the main criterion, which is the degree of dependence on the animals raised.

Figure 16. *Number of goats and sheep per rural inhabitant in Mali.*



Somewhat arbitrary limits were set when the degree of dependence on livestock products was classified. A system in which more than 50% of gross revenue (the value of subsistence plus marketed production) or more than 20% of household food energy was directly derived from livestock or livestock-related activities was classified as a pastoral system. One which derived between 10 and 50% of gross revenue from livestock, in other words 50% or more from agriculture, was classed as an agropastoral system. A third system, in which less than 10% of revenue was derived from livestock, might have been classified as 'agricultural' system but lay outside the scope of this study as was a possible fourth 'urban' system. It should also be pointed out that the concept of gross revenue includes the theoretical value of camels or other species as transport animals, and the value of cattle for traction and manure production. An indication of the degree of dependence on livestock in different production systems in Mali and the West African Sahel is given in Table 4.

The two main criteria thus give rise to two major production systems, pastoral and agropastoral, each with a number of subsystems. These subsystems are shown in Table 5, in which the main characteristics of each are listed. Three pastoral subsystems can be identified. The first is a 'pure', mainly camel-based, system in the northern arid zone, characterised by high mobility, and having almost no direct links with agriculture. The second, found in the northern central and northwestern semi-arid areas, is one in which animal production is associated with dryland cropping, with some cultivation and the exchange of manure for stubble grazing. Cattle, goats and sheep are the main species raised. In the third subsystem, specific to the inundation area of the Niger river and its hinterland, animal production is linked with floodplain grazing and farming; cropping is more important here and cattle are the main species raised.

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

Table 3. *Distribution of people and animals by ecological zone in Mali.*

Zone	Area		Rural population		Camels		Cattle		Sheep and goats		TLU[a]	
	(km^2)	(%)	('000)	(%)	('000 head)	(%)	('000 head)	(%)	('000 head)	(%)	('000)	(%)
Arid zone	856	(70)	815	(15)	164	(91)	939	(21)	3 596	(43)	1 277	(28)
Semi-arid zone	191	(16)	2 355	(43)	15	(8)	1 468	(32)	2 418	(25)	1 380	(31)
Subhumid zone	129	(10)	1 514	(27)	–	–	1 009	(22)	790	(10)	832	(19)
Inner Niger delta	54	(4)	840	(15)	–	–	1 114	(25)	1 439	(18)	993	(22)
Total	1 230	(100)	5 522	(100)	180	(100)	4 530	(100)	8 293	(100)	4 482	(100)

[a] One camel = 1.0 TLU; one head of cattle = 0.7 TLU; one goat or sheep = 0.1 TLU.

millet, sorghum, groundnuts and cotton being the main crops. The technical part of this report deals mainly with the first and second of these agropastoral subsystems.

An approximation of the distribution of livestock in the different production systems is given in Table 5. This suggests that 30% of livestock in the semi-arid zone belong to the agropastoral system, while the remaining 70% belong to the pastoral system associated with rainfed cropping. In the arid zone, 50% of the cattle and 70% of the small ruminants are raised under the pure pastoral subsystem, the remainder being associated with the rainfed millet subsystem.

The relative importance of the domestic species found within the systems and subsystems varies considerably. The only exception relates to camels, which are confined almost exclusively to the pure pastoral subsystem in the arid zones although a few are found in the pastoral/dryland cropping subsystem. However, even in the pastoral system, camels are numerically unimportant compared to cattle or sheep and goats. Because of their size and cash value, cattle certainly constitute the most important species in all the systems, economically if not culturally, and irrespective of whether their role is primarily milk production (as in the pastoral systems), draught power (as in the agropastoral systems), or a combination of these two roles plus meat production where system boundaries are not clear-cut. In the urban system, donkeys would replace cattle, to be followed closely by goats, as the most important species. In terms of TLU, cattle dominate the livestock sector in Mali (Table 3), although the numbers of both sheep and goats are probably considerably and consistently underestimated. Sheep are extremely important in the pastoral system, espe-

Table 4. *Dependence on livestock in different Sahelian production systems.*

System, country, ethnic group	Percentage of gross revenue from livestock	Percentage of total kcal consumed			Year	Source
		Milk	Meat	Cereals		
Pure pastoralism						
Mali						
Northeastern Tuareg	99	68	8	24	1971	(1)
Niger						
Tuareg	80	51	3	47	1963	(1)
Fulani	96	39	2	58	1963	(1)
Chad						
Annakaza	–	48	–	24	1950	(1)
Pastoralism/ rainfed cropping						
Burkina Faso						
Fulani	78	12	3	85	1977	(2)
Niger						
Fulani	–	24	2	74	1963	(4)
Tuareg	–	33	2	65	1963	(4)
Tuareg	–	17	3	80	1976/7	(3)
Pastoralism/ floodplain farming						
Mali						
Fulani	57	25	–	75	1958	(5)
Agropastoralism						
Mali						
Bambara	10	0.5[a]	0.8	95	1974/5	(6)
Burkina Faso						
Mossi	10	–	–	–		(2)

[a] Probably underestimated.

Sources: (1) Swift (1979a, b); (2) Delgado (1978); (3) Eddy (1979), but kcal values recalculated using 850 kcal/kg for milk and 1450 kcal/kg for meat; (4) Swift (1979a); (5) Swift (1979a) quoting Gallais (1977); (6) IER (1975).

Table 5. *Main characteristics of livestock production systems in West Africa.*

Characteristic	Pastoral systems			Agropastoral systems		
	Rice	Associated with rainfed agriculture	Associated with irrigation	Associated with subsistence rainfed agriculture	Associated with irrigation	Associated with cash crop, rainfed agriculture
Contribution of livestock to revenue (%)	95	90	60	25	15	10
Rainfall (mm/year)	<400	300–600	variable	400–800	variable	700–1400
Relations with agriculture	weak	some cultivation, exchange of manure	own fields cultivated	own fields cultivated, animal traction and crop residues are important		
Number of TLU/100 ha	0.0–3.9	4.0–17.9	10.0–27.9	4.0–9.9	10.0–17.9	4.0–17.9
Carrying capacity						
People	very low	low/medium	high/very high	medium	high	medium
Animals	low	low/medium	medium/high	low/medium	medium/high	medium/high
TLU per person[a]	0.0–1.6	0.4–1.6	1.2–1.6	0.4–1.2	0.4–1.2	0.4–0.8
Mobility	high, no fixed base	medium, fixed base	high in wet season	low and for short distances during the main cultivation season		
Importance in						
Mali	high	medium	medium/high	high	high	high
Mauritania	high	low	low/medium	medium	low	low
Niger	high	high	low/medium	medium	low	medium
Senegal	low	low	low/medium	high	low/medium	high
Burkina Faso	low	medium	low	high	low	medium/high

[a] Range of ratios.

cially in the northern and floodplain areas. In the agropastoral system, goats are much more important than sheep, at least at the level of the individual producers.

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 in these subsystems also play a large, if usually unpublicised, role in providing transport for agricultural products and fuelwood. Horses are of minor importance in all systems, perhaps vested with the only remaining traces of the prestige syndrome once considered to be the principal preoccupation of livestock owners.

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

Livestock also play a role in savings, the returns from agriculture being diverted to this end in the absence of alternative forms of investment. In fact, there is considerable evidence that rapid changes in ownership are taking place and that these are not only among farmers. The new owners include civil servants, service personnel and merchants as well as agriculturalists who invest 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.

Subsystems in the agropastoral system

Table 6 lists some of the main differences between the millet and rice subsystems which might account in large part for performance differences between the two. The rice subsystem appears to have certain advantages over the millet subsystem, which may lead to increased productivity. In the rice subsystem, for instance, the stall-feeding of castrate sheep, known throughout francophone West Africa as the *mouton de case* system, is much easier owing to the greater availability of crop residues (Kolff and Wilson, 1985). Water is also abundant all the year round, whereas in the millet subsystem it is restricted during the dry season.

Table 6. *Management and environmental factors in the millet and rice subsystems in central Mali.*

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

4. MATERIALS AND METHODS

THE STUDY HERDS AND FLOCKS

Following a preliminary survey in early 1978, herds and flocks in six locations in the millet subsystem and in four locations in the rice subsystem were selected for study. These units were then followed on a regular basis until June 1984. At the start of the survey there were approximately 600 head of cattle in the herds and some 700 head of goats and sheep.

At the end of June 1984, when the analysis was undertaken, there were records for over 1150 cattle and 5000 small ruminants, both these totals including those animals that were present at the beginning of the study. Most of the animals entering the herds did so by birth, although there was a small number of purchases and some animals were brought in as gifts, loans or exchanges.

FIELD METHODS

At the start of the survey, all cattle were individually identified by means of numbered plastic or metal ear tags. Details of the animal's age (determined by dentition and/or by owner questioning), its function in the herd and its reproductive history (if a female) were obtained. From these data, an individual record card was established. All animals subsequently entering the herds were treated in the same way, and individual record cards were also created for these animals.

Visits were made to cattle herds on a regular basis, usually at intervals of about 4 to 6 weeks but more often during the main calving period of late April to early August. Owners cooperated in defining the events – births, deaths, purchases and sales – which had taken place during the time period which had elapsed since the previous visit. Details of all these events were entered on the individual record cards or new record cards were created, as appropriate.

Goat and sheep flocks were visited at intervals of about 15 days. Young animals were weighed on most of these occasions, while older animals were weighed on every second visit.

Lighter animals (estimated as less than 100 kg) were weighed on most of the regular visits by suspending them in a sling attached to a dial-type spring balance. Heavier animals were weighed in a proprietary brand, transportable weigh crush. Weighings of heavier cattle were made at less frequent intervals, usually four times each year: these were timed to coincide with the end of the rains (September/October), the beginning of the dry period (late November to early January), the early part of the hot dry period (March/April) and the end of the dry season and beginning of the rains (July). On occasions, logistical and administrative problems made it impossible to adhere to this timetable. Some weighings of adult cattle therefore appear in the records for other months of the year.

DATA ANALYSIS

The individual records for each animal were entered on a computer and the following subsets were established from the main data base, relating to the animal's identity and aspects of its productivity:

- Identity: individual number, system of management, herd identity, reason for entry, sex, parity, type of birth, date of entry, reason for exit, dam number.
- Reproductive performance: age at first parturition, date of parturitions, interval between successive parturitions, identity of young, sex of young, the parity (order in its dam's reproductive record) of young. Where previous reproductive history of cows of mature age was unknown, the first

recorded parturition was set arbitrarily at three, and where this parameter was unknown for goats or sheep, the first recorded parturition was set at four.

- Weight: two subsets were established; one for animals of known birth date from which it was possible to calculate growth rates and the effect of some variables on it, and one for animals of unknown birth date which was used primarily for establishing weights for age in the older age groups and for determining the magnitude of seasonal weight changes in these animals.
- Dentition pattern: for a small number of animals this was used to determine ages at eruption of permanent incisors, but the main use of this subset was in the weight-for-age data at older ages.
- Milk production: small sets of records were established on milk offtake for human consumption for a few animals in one herd of cattle and for the total milk production of some Macina sheep.

Usual compilation and statistical techniques using a pocket calculator were used for many preliminary analyses and as an aid to verification and preparation of data. Most final analyses were carried out using recognised software packages, particularly SPSS, BMDP, GLIM and the Harvey (1977) model for the generalised least-squares procedure suitable for use on data with unequal subclass numbers. The estimated least-squares means generated by this analysis, being adjusted for the unequal subclass numbers, may differ from the observed means.

Effects in the Harvey model usually included the fixed effects of:

- subsystem: millet, rice
- month of parturition or birth
- parity: 1, 2 ....n and '9' when unknown but considered to be ≥3 for cattle and ≥4 for small ruminants:
- type of birth: single, twin, triplet or multiple where twin and triplet births were combined
- sex: female, male
- herd within system
- year, and
- interactions of some of the above main effects.

When adequate data were available, the random effects of dam within flock or within system were used in a mixed model.

The residual mean square was used as the error term in the Harvey model to test the significance of all differences. Linear contrasts of least-squares means were computed to determine the significance of differences between groups.

For cattle, a total of 519 births from 274 cows or heifers and 244 calving intervals were recorded during the study. The weights of animals of known birth date totalled almost 6000 records: all weights, including those from mature animals, totalled over 10 000 records.

In small ruminants, 3605 parturitions gave rise to 4049 young and more than 2000 parturition intervals. Almost 40 000 weights were recorded.

ADDITIONAL SOURCES OF INFORMATION

Considerable additional information was obtained from primary or secondary sources and has been incorporated in this report. In particular, this information related to the production systems (Section 3), to the general field of management (Section 5), to herd demography (Section 6) and to some aspects of reproductive performance (Sections 7 and 11) and productivity (Sections 10 and 14).

This information was obtained by means of:

- specific short-term studies,
- direct observations in the field,
- structured and unstructured interviews with owners and herders,
- data collected by students of the Rural Polytechnic Institute, supervised by ILCA staff and published as dissertations,
- information extracted from internal reports (Programme Documents) of the Arid and Semi-arid Zones Programme, and
- other relevant literature.

These sources have been acknowledged in the text and listed in Part 5 of this report.

5. MANAGEMENT

OWNERSHIP PATTERNS

The numbers of households and people who own cattle, as well as the actual numbers owned, vary between the rice and the millet subsystems. The farming system practised is also reflected in the ownership of farm equipment. In Table 7, some of these differences are shown for the two subsystems in central Mali. The higher percentages evident for rice farmers result partly from a readier access to credit through the parastatal irrigation scheme, the Office du Niger.

Ownership patterns established from official statistics give only a general idea of the variations in numbers of people owning livestock and of the importance of the animals in the whole system. In the Niono area the Office du Niger carries out its own 'census' of animals within the irrigated perimeter. Its figures are additional to the official administrative census and there is seldom any relationship between the two. Our own observations have shown that the Office du Niger has no apparent interest in small runminants, and these classes of stock are largely ignored in their census. The figures for small ruminants are not only misleading in terms of ownership and total numbers but also in respect of the ratio of goats to sheep. In the official census, where goats and sheep are counted separately (it being evident from Table 7 that this is not always the case), individual families are usually shown to have equal numbers of each. Our own observations confirm the numerical importance of goats over sheep at a ratio of 5.4:1 in the millet subsystem and 1.4:1 in the rice subsystem. Table 8 details the ownership patterns of 43 small ruminant flocks in the Niono area censused by us.

The ownership of principal means of production, work oxen and ploughs, is also rather uneven, especially within the millet subsystem. As can be seen from Figure 17, most families own only one plough while a smaller number own pairs of oxen. It might be inferred from this that there is a tendency for a plough to be acquired before oxen, and that the hiring and renting of oxen are not uncommon practices in the area.

Some additional data relating to ownership patterns are presented in Table 9 for various ethnic groups and subsystems. It needs to be stressed that all the animals in individual ownership are rarely herded as a single unit; a family may split its herd and put a number of animals into several other groups for the purposes of day-to-day management. In the case of cattle such groups vary in size from about 50 to 200–300 head, depending on the system, the nature of the terrain and the time of year. Occassionally, bigger herds of over 500 head may be constituted. The ownership structure of such herds is usually very complex (Table 10).

MOVEMENT

The extent of movement varies with a number of factors. These include the need to keep animals away from crops during the growing season, the principal occupation of the owner, the necessity of searching out the best fodder and water resources in the dry season, and the need to escape from the Niger floodplain during the period when this is inundated.

The longest annual movements are undertaken by the Fulani who normally reside in the inundation zone. Beginning in July each year, these people make treks of 300 km to the Mema and to southeast Mauritania. The reverse journey is made in October after the short Sahel rains have stopped and the annual flood in the inundation zone begins to recede. Similar but shorter seasonal treks are made into the Seno-Mango, southeast of the floodplain, with some herds con-

Table 7. *Holdings of livestock and farm implements according to official statistics for a sample of villages in the millet and rice subsystems of central Mali.*

Subsystem/village (No. of households)	Cattle		Sheep		Goats		Donkeys		Ploughs	Carts
	% owning	range in numbers[a]	% owning	range in numbers	% owning	range in numbers	% owning	range in numbers	% owning	% owning
Millet[b]										
Pogo (62)	71.6	1 – 79	70.0	1 – 50	80.0	2 –150	51.7	1 – 4	66.7	43.3
Kamono (10)	100.0	1 – 50	90.0	5 – 60	80.0	8 – 60	80.0	1 – 2	80.0	70.0
Sissako (33)	75.8	1 – 40	81.8	3 – 20	87.9	5 – 20	36.4	1 –10	45.5	24.2
Teninzana (29)	72.4	2 – 30	72.4	5 – 55	75.9	5 – 55	65.5	1 – 3	62.1	20.7
Siguine (21)	80.9	1 – 25	85.7	2 – 35	85.7	2 – 35	71.4	1 – 2	57.1	23.8
Thing (40)	75.0	1 – 50	77.5	2 – 66	75.0	3 – 66	57.7	1 –22	60.0	50.0
Siraouma (26)	96.2	1 – 12	0.0	–	88.5	5 – 20	53.9	1	84.6	57.7
Ndebougou (114)	53.5	2 – 30	0.0	–	54.4	2 – 30	44.7	1 – 2	40.5	5.6
Ntila (62)	38.7	2 – 22	3.2	2	38.7	2 – 50	29.0	1 – 3	27.4	1.6
Bamada (39)	23.1	1 – 14	5.1	2 – 8	20.5	1 – 15	30.8	1 – 3	41.0	28.2
Rice[b]										
N6 (35)	85.7	2 –140	0.0	–	8.6	10 – 18	60.0	1 – 2	71.4	57.1
N9 (72)	63.9	2 – 40	1.4	5	4.2	5 – 10	43.1	1 – 2	59.7	34.7
N5 (27)	85.2	2 – 50	21.7	2 – 10	0.0	–	48.1	1 – 2	92.6	48.2
N10 (53)	83.0	1 – 38	0.0	–	3.8	5	54.7	1 – 2	84.9	77.3
B1 (55)	96.4	1 – 39	7.3	1 – 3	21.8	1 –	70.9	1 – 2	98.2	67.3
B6 (39)	89.7	1 – 15	33.3	1 – 8	33.3	1 – 8	69.7	1	100.0	54.6

[a] Nil holdings excluded for all species.

[b] Data for the millet subsystem were taken from the administrative census; those for the rice subsystem from the Office du Niger census.

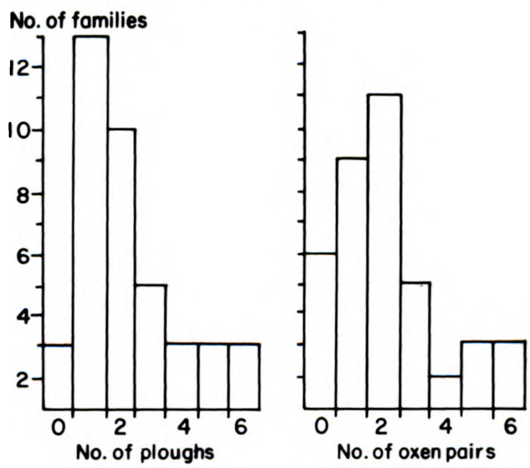
Table 8. *Ownership pattern and flock sizes for small ruminants in the agropastoral system of central Mali.*

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

[a] Irrespective of whether the holding of one or both species is nil.

[b] Nil holdings excluded.

Figure 17. *Ownership of ploughs and oxen pairs in a central Malian village.*



tinuing south into Burkina Faso. The Moors also spend the rainy season in Mauritania and move south to Mali in the dry season. Here, they pasture their animals on the crop residues of the Bambara sedentary cultivators, providing manure in exchange for water from wells which the farmers have dug in their fields (Figure 18).

The animals owned by the cultivators of the Office du Niger irrigation scheme migrate over shorter distances. Except for a few work oxen, cattle in this subsystem move out of the irrigated area at cropping time. On returning to the irrigated area after the harvest, they benefit from the abundant crop residues, and certain groups, notably work oxen, may receive some special supplementary feeding. Cattle which move least are those of the rainfed millet cultivators and those owned by the urban populations in such centres as Ségou, Mopti and Niono. The latter are kept by town dwellers, including civil servants and military personnel, mainly as an investment or as a source of milk. A supply of milk for sedentary family members in other subsystems is assured by retaining a few milking cows at the homestead when other cattle go on their annual transhumance.

In the rainfed millet cropping zone sheep are managed under sedentary conditions, and seasonal movements, other than short-distance ones away from the farmed areas during the growing season, are not part of the management strategy. Some supplementary feeding is practised either from crop residues or from cut and carried browse (especially *Pterocarpus lucens*) during periods of food scarcity. In the irrigated rice areas of the Office du Niger the patterns are similar but more supplementary feeding is possible on account of the greater availability of crop residues and the fodder provided by weedy regrowth in fields and on the borders of irrigation canals. Goats are more important than sheep in these primarily agricultural areas, outnumbering sheep in a ratio varying from 1.7 to 2.7:1.

A transhumant system of management – in which animals migrate seasonally but return to a fixed base – is practised by the agropastoral Fulani of the inundation zone, the Fulani of the Gourma, the Moors and some Tuareg who live close to the Niger river.

The Fulani of the inundation zone cultivate rice under the annual flood regime of the Niger. Because of the flood they are forced to move most of their sheep on to the adjacent dry areas each year. The extent of this movement can be judged from Figure 19. The Fulani also have a sophisticated system of flock stratification (Table 16) which involves leaving some sheep behind on the

Table 9. *Ownership of cattle and other stock by different ethnic groups in central Mali.*

Group/subsystem	No. of households	Average household size	No. (average or range) of animals owned per household			
			Cattle	Goats and sheep	Camels	Donkeys
Bambara/sedentary, millet	30	16.7	25.0	31.7	0.0	2.1
Rimaibe/sedentary, millet	29	6.4	5.2	20.3	0.1	1.7
Fulani/transhumant, millet	27	7.5	24.5	9.5	0.3	0.1
Fulani/professional herders	10	5.0	1.0	35.0	0.0	0.0
Moor[a]/transhumant, millet	9	6	3–5	30–50	10–20	3–4
Tuareg[a]/transhumant, millet	–	17	30–50	50–60	2–3	2–3

[a] From Fofana (1974).

Table 10. *Structure of two cattle management units in the Niger inundation zone, by main profession of owner.*

Profession of owner	Structure (%)	
	Herd 1 (n = 220)	Herd 2 (n = 263)
Professional herder	23	18
Other livestock owner	37	32
Cultivator	2	3
'Investor'	13	30
Unknown	25	17
Total number of owners	48	29

village mounds in the flood area to provide milk for those family members remaining to cultivate the rice. Flock sizes are large with 69% of all flocks having more than 100 head. Goats are of little importance in this system, being outnumbered by sheep in the ratio of 7:1.

The Moors spend the rainy season in Mauritania where they cultivate small patches of bulrush millet (*Pennisetum typhoides*) on an opportunistic basis. They are drawn south to Mali during the dry season where fodder conditions on the open range are marginally better. The Moors have a close relationship with the settled cultivators in the areas in which they spend the dry season. This involves the cultivators' digging wells on their farmed land and offering the water to the Moors. The latter then camp on the farmed areas and their animals enrich the soil with their droppings and urine. Sheep are of relatively less importance to this group than to the Fulani of the inundation zone but still outnumber goats in the ratio of 1.6:1. Flock sizes generally exceed 80 head.

Transhumant Fulani roam over most of central Mali, following more or less fixed orbits, each one particular to its own area. Cattle are paramount to their way of life but small ruminants occupy an important subsidiary position, with sheep being outnumbered by goats in a ratio of about 1.0:1:6. The average flock size is about 25 head. Conflicts between the Fulani and settled cultivators are not infrequent towards the end of the cropping season, as Fulani cattle encroach on cultivated areas in their constant search for nourishment. On the other hand, the farmers are to some extent dependent on the Fulani for manure and they also make use of traditional Fulani husbandry skills by having them herd their own animals. Fulani in the drier areas of the Gourma have less contact with cultivators and have wider seasonal orbits than their contemporaries in the areas where rainfall is more regular.

Some Tuareg use the Niger river as a permanent focal point and cultivate either rainfed or 'falling-flood' crops to supplement income from livestock. Most Tuareg, however, are more typically nomadic with no permanent base and with almost all their income deriving from livestock. This would include cash income from transport of, for example, salt by camels, or of grain from cultivators to the market by camels or by donkeys. Sheep are milked by this group (as they are to some extent by the Moors), the milk being conserved in times of plenty as a form of hard curd. Sheep are more important than goats to the Tuareg, the ratio being 1.4:1 and flock size about 50 animals.

Some idea of the complexity of the movement patterns as practised by different ethnic groups in central Mali can be obtained from Table 11.

Figure 18. *Pastoral cattle feeding on stubble in an agro-sylvo-pastoral system in central Mali.*

GENERAL MANAGEMENT

Most livestock owners in developed countries would not consider the practices pursued by central Malian traditional owners to be 'management'. Nonetheless, the sum of such practices must be considered to constitute management.

Breeding in cattle or goats is not controlled, and the seasonality that occurs (Sections 7 and 11) is a result of the natural environmental conditions acting through the feed supply. Breeding control is occasionally practised for sheep, especially by the more mobile ethnic groups: the method used is the *kunan*, a cord stretched from the scrotum to the prepuce, which deflects the penis at erection thus preventing intromission.

Management of young stock is practised: young animals are not allowed out to graze until they are 3 to 4 months of age, and they are prevented from suckling when milk from their dams is required for humans (Figure 20). During this period, calves are restrained in groups by a simple individual rope halter attached to a long general line, also of rope. Lambs and kids are treated similarly or kept in the owners' houses. There is evidence (Diallo and Wagenaar, 1983) that some owners are aware of the milking capabilities of their cows and milk most heavily those cows with higher yields. Calves from such cows still grow at a faster rate than the offspring of lower-yielding cows.

The control and manipulation of the demography of the herds (Section 6) also indicates a level of management, the population structure being adjusted so that the herds or flocks are most productive under the prevailing circumstances. The seasonal movements already described in this section also constitute a carefully planned management strategy.

An example of the annual management of cattle in a sedentary village which takes in transhumant cattle during the dry season, is given in Figure 21. In such a village, it is very probable that the village-owned cattle will be herded by a professional herdsman of a different ethnic group who receives milk and possibly part of the calf crop in lieu of all or a portion of cash wages. He may also be allowed to keep one or two of his own animals in the herd.

In the agropastoral system, management at the micro-level is almost invariably comprised of herding by day (either in individually owned herds and flocks or in herding groups which are composites of several owners' animals herded on a rotational basis or by a professional herder) and close penning or individual attachment at night. In the dry season, and particularly in the upland millet areas, it is not unusual for goats (and occasionally sheep and cattle) to be unguarded during the day. The practice of not herding animals often results in considerable numbers of 'lost' animals. The numbers of lost animals vary between flocks. This is just one of the factors contributing to the great variations in overall flock productivity which will be discussed further in the relevant sections on cattle and small ruminants.

Figure 19. *Landscape units of the Niger inundation zone and seasonal distribution of Macina sheep.*

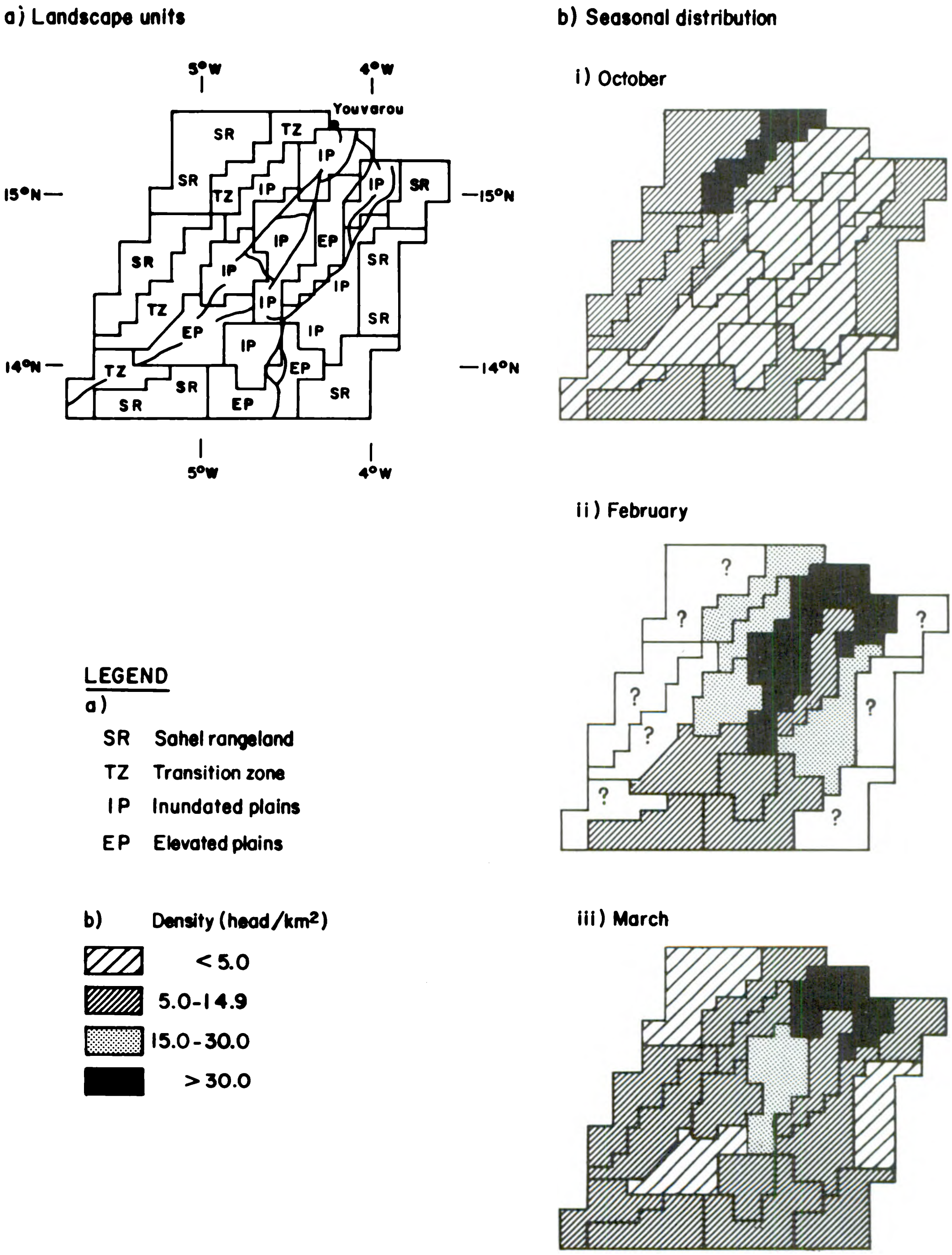


Table 11. *Seasonal distribution of livestock according to ownership groups.*

Wet-season grazing areas	Dry-season grazing areas			
	Deep wells in 'Sahel' and millet areas	Irrigated rice areas	Delta area	
			'old' *burgu*	'new' *burgu*
Northern pastoral areas ('sahel')	Maure	Fulani without traditional rights in the delta	Tuareg dependants	Fulani with traditional rights in the delta
Rice subsystem	Maure dependents	Rice farmers	Merchants using Fulani herders	Fulani dependants
Millet subsystem	Millet farmers	Merchants	Civil servants	Fulani livestock traders

In an agricultural village, the management of work oxen differs from that of the general herd. In the dry season, they are herded with the bulk of the village cattle on fields close to the homestead. Late in the dry season or very early in the wet season, they are withdrawn from the main herd which goes on its annual short transhumance. The oxen are then kept in the house compound at night while being allowed to continue grazing freely throughout the day, when not required for ploughing or transport purposes. Supplementary feeding is not very common (although its incidence is perhaps increasing) but some household salt, or salt of other type, may be provided during this season.

MANAGEMENT CASE STUDIES

Mouton de case in the Niono area

Almost all West African animal husbandry is of an extensive nature. Occasionally a few animals, particularly sheep, are kept under more intensive conditions. This smallholder fattening is generally known as the *mouton de case* system and can be defined as one in which sheep are tethered or confined near the house of the owner and receive a supplement of good-quality roughages and concentrates (Figure 22). The system uses male sheep in the main, these being selected out of the flock or specially bought for fattening over a relatively short period. It is most common where a high

Figure 20. *A net pouch of baobab string used to restrain calf suckling.*

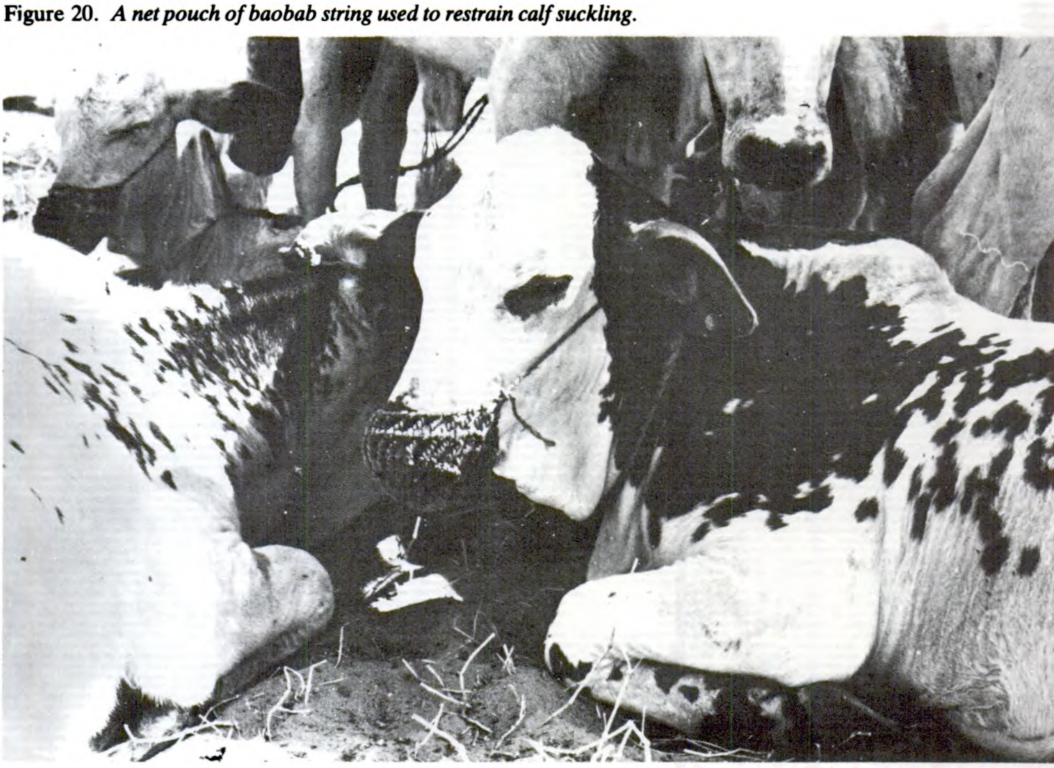
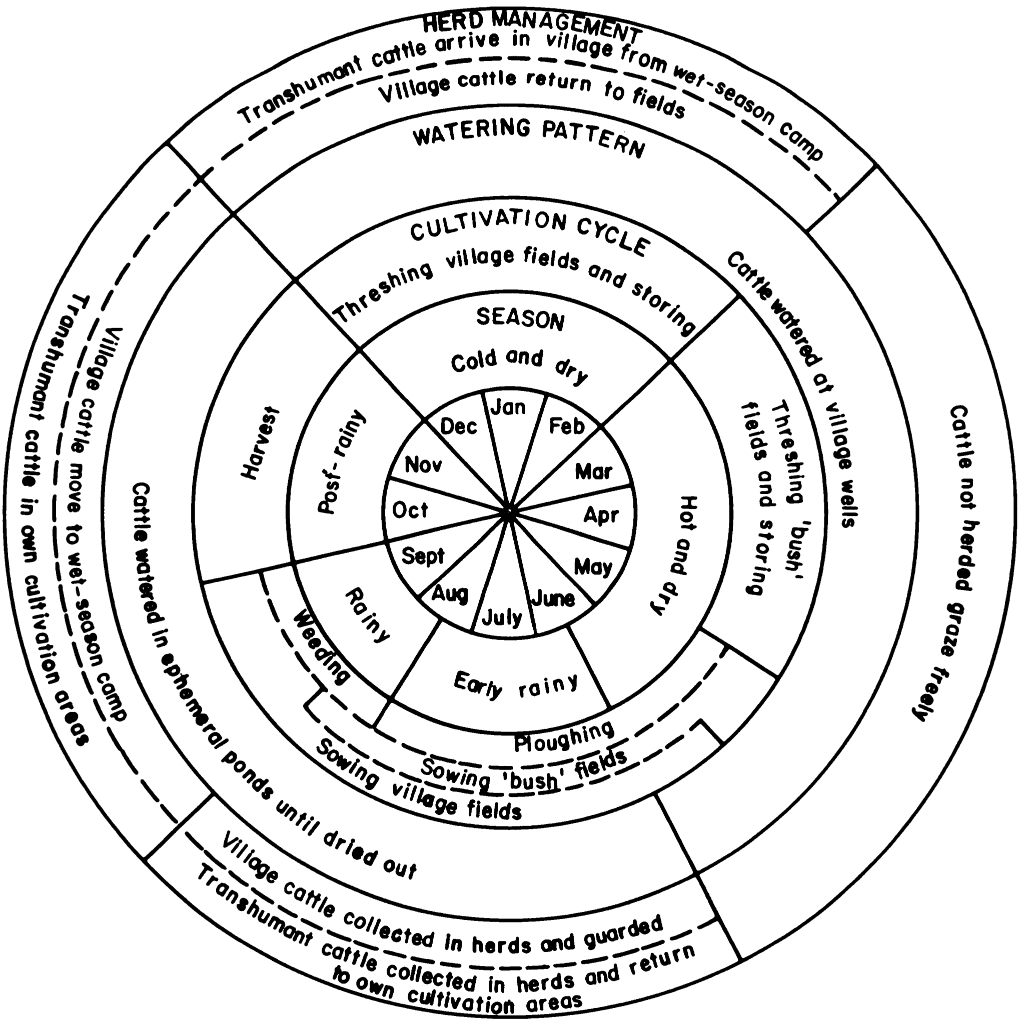


Figure 21. *Annual pattern of cattle management in a sedentary village in central Mali.*



proportion of the population is devout Moslem, as one of the principal reasons for this fattening system is to have a sheep for slaughter (or for sale) at the annual religious festival known as *Tabaski*.

Although this system is supposedly common, it is often difficult to distinguish between it and more extensive ones (Coulomb et al, 1980). In Chad, Dumas (1978) felt that several problems needed to be overcome before a definition of *mouton de case* could be finalised. In an attempt to define more precisely this special case, a specific study was undertaken. Management data were collected from five rice and six millet villages with totals respectively of 123 and 71 confined sheep.

Of the 159 and 148 households visited in the rice and millet subsystems, 39% and 24.3% respectively kept *moutons de case*. The differences between the subsystems just failed to be significant at the 5% level ($X^2 = 3.43$, d.f. = 1). The mean number kept per owning household was almost the same being 1.98 in the rice subsystem and 2.19 in the millet subsystem, with a considerably greater percentage of millet households owning two sheep (Figure 23).

Not all animals being fattened are confined for whole periods of 24 hours, this factor in part leading to the difficulty of defining a *mouton de case*. Of the 194 sheep in the 11 villages visited a total of 54 (27.8%) were not continuously tied up. There were no significant differences ($P>0.05$) between the rice (28.5%) and millet (26.8%) subsystems in this practice.

The relationships between the keeping of *moutons de case* and three other classes of stock (work oxen, all other cattle and total sheep) were also examined. Table 12 shows the regression analyses calculated on the data obtained on own-

Figure 22. *A mouton de case ram in a stall in central Mali.*

ership of the other three classes of stock. Significant positive correlations were found between the keeping of *moutons de case* and all cattle in the rice subsystem. There were no significant correlations between the keeping of *moutons de case* and all cattle in the millet subsystem and total sheep kept in either subsystem.

Not all confined sheep are kept with slaughter or sale in view. A proportion is kept for breeding, this being equivalent to 15.4% in the rice villages and 25.7% in the millet villages. The difference just failed to be significant between systems at the 5% level (X^2 = 3.62, d.f. = 1). Only two of the 39 sheep said to be kept for breeding, one in each subsystem, were males. No females were kept for slaughter or sale purposes. The breakdown by sex and by age of sheep kept confined for whatever period is shown in Tables 13 and 14. There were no significant differences (P>0.05) between subsystems for either sex or age distribution.

There were no significant differences (X^2 = 3.48, d.f. = 1, P>0.05) between the subsystems in sheep being fattened for sale – 56.7% in the rice villages and 78.4% in the millet villages – but there was a significant difference (X^2 = 7.14, d.f. = 1, P<0.05) in those being kept for home slaughter in the rice subsystem (40.3%) and in the millet subsystem (19.6%). The fate of the remaining 2.9% and 2.0% in the respective subsystems had not been decided at the time of the enquiry. A slight majority of all animals (59.6% and 41.2% respectively in the two subsystems) was destined for slaughter at the current year's *Tabaski* ceremony.

In the rice subsystem, 76.4% of confined sheep were bought compared to 38% in the millet subsystem, this difference being significant at the 5% level (X^2 = 6.44, d.f. = 1). Birth in the owner's flock was the reason for entry for 23.6% of sheep in the rice subsystem and 50.7% in the

Figure 23. *Ownership of moutons de case in the rice and millet subsystems.*

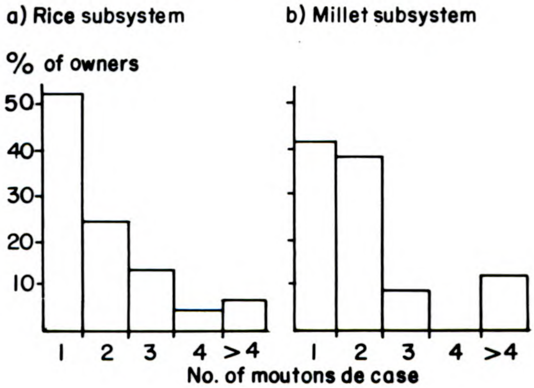


Table 12. *Regression analyses and correlations between the ownership of moutons de case and other classes of livestock.*

System	Class of stock	Calculated regression		Statistical value		
		a	b	d.f.	r	P
Rice	Work oxen	3.6	25.6	4	0.943	**
	All cattle	1.8	31.5	2	0.979	*
	All sheep	0.3	43.4	3	0.155	n.s.
Millet	Work oxen	5.7	20.4	4	0.926	**
	All cattle	2.5	35.0	2	0.890	n.s.
	All sheep	1.1	39.0	3	0.850	n.s.

Notes: a = slope, b = intercept.

**P<0.01; *P<0.05; n.s. = not significant.

Table 13. *Percentage distribution of all confined sheep by sex.*

Sex	System	
	Rice	Millet
Male, entire	79.9	72.9
Male, castrate	4.9	1.4
Female	15.4	25.7

Table 14. *Percentage distribution of confined male sheep by age group.*

Physiological age	System	
	Rice	Millet
Milk teeth	50.0	49.0
Permanent incisors		
1 pair	21.2	23.5
2 pairs	4.8	7.8
3 pairs	0.1	3.9
4 pairs	0.0	15.7
Unknown	24.0	15.7

millet subsystem, the difference again being significant at the 5% level (X^2 = 9.88, d.f. = 1). In the millet subsystem, owners were unable to give the precise entry reason for 11.3% of animals.

The number of months during which male sheep (excluding animals kept for under 1 month) had been confined is summarised in Figure 24. The most common period was between 4 and 6 months in both subsystems (34.6 and 35.3% of all sheep). However, in the rice subsystem, significantly (X^2 = 5.97, d.f. = 1, P<0.05) more sheep (24% of all animals) were confined for a period of 7 to 9 months than in the millet subsystem (9.8%). The reverse was the case for animals confined for more than 12 months, with significantly less sheep (X^2 = 12.85, d.f. = 1, P<0.001) being confined in the rice subsystem (8.7%) than in the millet subsystem (39.4%).

A wide variety of green fodder roughages and crop byproducts was fed to the sheep. Seasonal availability was obviously a major factor in determining what feedstuffs were fed at any given period. It was, however, the system which had the greatest effect on the type of feed fed.

Table 15 summarises for each subsystem questionnaire responses on the agricultural byproducts and salt offered by 62 owners with 123 sheep in the rice subsystem and 36 owners with 79 sheep in the millet subsystem. Rice products were fed by a significantly greater number of owners in the rice subsystem than in the millet subsystem. The number of rice growers feeding cotton seed was also significantly greater than that of millet growers feeding it. More rice owners fed sweet potato haulm than did millet owners, although this difference was not significant. Millet,

Figure 24. *Length of confinement for moutons de case in the rice and millet subsystems.*

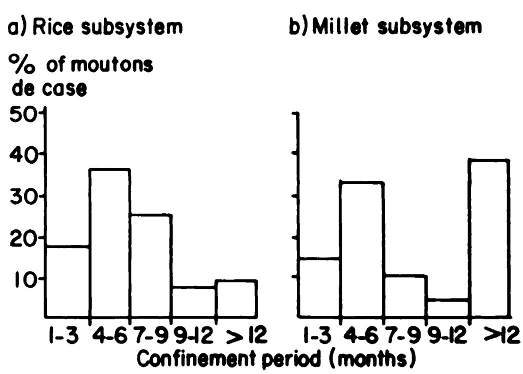


Table 15. *Percentage of owners offering different types of feed to moutons de case in the rice and millet subsystems and percentage of owners offering who buy the products.*

Type of feed	Percentage of owners offering		Percentage of those offering who buy	
	Rice subsystem (n = 62)	Millet subsystem (n = 36)	Rice subsystem (n = 62)	Millet subsystem (n = 36)
Rice *(Oryza sativa)*				
Straw	27.4	0.0	0.0	0.0
Grain	27.4	0.0	5.9	0.0
Bran	88.7	17.7	40.0	100.0
Millet *(Pennisetum typhoides)*				
Grain	24.2	77.8	53.3	10.7
Bran	54.8	99.4	44.1	5.9
Cotton *(Gossypium hirsutum)* seeds	16.1	5.6	100.0	100.0
Cowpea *(Vigna sinensis)* haulm	45.2	75.0	3.6	0.0
Groundnut *(Arachis hypogaea)* haulm	17.7	75.0	0.0	0.0
Sweet potato *(Ipomoea batatas)* haulm	52.6	36.1	0.0	0.0
Salt	67.7	83.3	100.0	100.0

cowpea and groundnut products were fed by a significantly greater number of millet- than rice-growing owners. The percentage of owners offering salt did not differ significantly between subsystems.

With the general exception of salt and cotton seed, most other products were home produced (Table 15). Exceptions to this general statement are that all the millet farmers who fed rice bran had to buy it and a proportion of rice farmers who fed millet products also needed to buy those. These figures need to be viewed with some circumspection as feedstuffs were not bought entirely for feeding to *moutons de case*, and their use for fattening animals was often to the detriment of the work oxen for which much of them were primarily destined.

Feedstuffs of non-agricultural origin were also provided in both subsystems although in a much wider variety in the rice than in the millet subsystem. In the rice subsystem, in addition to grass, the leaves of a locally grown *Ipomoea* sp. were most commonly fed, followed by those of *Khaya senegalensis* (an introduced shade and timber tree whose leaves are not selected on the tree by free-ranging animals) and *Pterocarpus lucens*. Leaves from a further nine plant species were identified in the rice subsystem and other species were undoubtedly fed. In the millet subsystem, *P. lucens* was the unique non-agricultural feed offered. All feedstuffs in this category were cut and carted by family labour although there is an active commercial trade in most of these items in the Niono urban centre.

Management of Macina sheep in the inundation zone

Macina sheep are managed under a transhumant system, its base being in the 'inundated' (i.e. the lower-level) plains of the inundation zone. The hydraulic regime of this zone is such that the area is under the flood waters of the Niger from late July or August through to February or March, although the southern parts of the zone begin to dry out in November or December following the retreat of flood water northwards. The majority of animals must thus leave the zone on annual migration in early July. The migration route for most of the sheep is to the north and west, where there is typical Sahelian pasture. The emigration from the inundation zone coincides with the short Sahelian rainy season so the sheep are, at least to some extent, still in conditions (green pastures and a humid climate) which are favourable to them. The extent of the seasonal movement and its intensity can be gauged from Figure 19 which shows the densities and distribution of small ruminants at the end of the rainy season, when the central zone is still inundated, and in February and March, when the floods have receded. While distances are relatively short, there is an almost total evacuation of animals from the 'inundated' plains to the 'transition' zone in the northwest and, to a lesser extent, to the 'Sahel' pastures farther northwest and to the east. This movement is paralleled by that of cattle although these animals move over much longer distances.

During the flood season some 80% of sheep are found outside both the 'inundated' and 'elevated' plains of the central zone, leaving some 50 000 head only in this area at a density of about three animals per km^2. These sheep are mostly on the small eminences within the floodplains on which permanent village bases are established. After the flood has fallen the situation is almost exactly reversed, with 70% of all small ruminants found on the plains at a density of 8 per km^2 on the elevated and 20 per km^2 on the inundated plains.

The Fulani shepherds recognise four seasons: *indiewde*, which is roughly the post-rains period of October and November; *dabunde*, the cold dry period from December to February; *cedu*, the hot dry season of March to June; and *ndungu*, the rainy season of July, August and September. Major movements are governed by the seasonal calendar which in itself is subordinate to the flood regime. The wet-season transhumance cycle is dictated to some extent by the needs of the sheep for a mineral supplement, which is usually provided by salt earths although salt may occasionally be bought.

The main body of sheep move back into the inundated plains at the start of the *cedu*, but the factors which govern the actual timing include the extent to which the pastures have dried out, the occupation of the area by cattle-owning groups who have precedence, and the whim of the 'chief shepherd' who is the elected representative of a village or area and who is usually the largest owner. For obvious reasons it was not possible to obtain much information on actual ownership patterns. Management units (flocks) in the transhumant system are usually large but some stratification is practised. The inundation zone is a series of water meadows topographically flat, with good visibility and a dense herbage cover. There are thus advantages in maintaining large grazing groups under the responsibility of one or two herders. During the period spent in the inundation zone itself these groups are seldom composed of less than 300 head and more than 500 head is not uncommon. In an intensive ground survey, 69% of all groups in the flood zone were greater than 100 head in size and a further 23% were between 50 and 100 head. The analysis of aerial survey results showed a similar situation with some 75% of groups having more than 100 head of sheep in the 'Sahel' and 'transition' land units during the rains. That these were mainly Macina groups was easily confirmed by the homogeneity of colouring as opposed to the varied colours of mixed flocks of hair sheep and goats.

Because of the need to ensure a constant supply of milk and meat for the family members remaining in the inundation zone during the flood season, a sophisticated system of stratification has developed. This is undoubtedly based in part on a similar system used by cattle-owning Fulani, although the terms used and the type of groupings are not generally the same. The principal characteristics of this stratification are shown in Table 16.

In 85% of cases weaning takes place at about 4 months, usually by removing the lambs to another management group. Where this is not possible the teats are blocked with dung or tied with a cord. Castration is carried out either shortly after weaning (at 6 or 7 months in 30% of cases) or at about 1 year (48%). The common practice is attrition of the cord by beating with two sticks although the open method is occasionally used. There is little or no attempt to control breeding season, but most owners (74%) thought that the main tupping period was during the rains, giving rise to births in the latter part of the cold season or in the early hot season.

Shearing, if such it can be called, is done with a double-bladed knife. In general this activity can be considered the poorest of the management practices of the traditional husbandman. Individual sheep are shorn as many as four times in a year. It is perhaps worth noting that the French colonial power enacted legislation regulating the number (two) and the timing (before and after the rains) of shearings: at independence this law passed into the Malian code but, while still on the Statute Book, its existence is ignored by the owners and the responsible livestock authorities have neither the personnel nor the logistic support to enforce it. There is generally no specific period assigned to shearing nor are all sheep in one flock shorn together. There is thus a constant source of new wool for spinning and weaving by the local village industry, with supply being perhaps geared to periods when labour would otherwise not be utilised.

Table 16. *Stratification of Macina flocks with demographic characteristics and management objectives of each group.*

Flock name	Group size	Use	Composition			Notes
			General	Males (%)	Females (%)	
Beydi	Generally small	Nurse flock	Newly lambed females, ewes in advanced pregnancy, weak and aged animals	26	74	Kept in the village; herded by infants. Regular movements of animals into and out of this group.
Tarancaradji	Medium	Sale/ slaughter	Largely male, generally young, with some older females	60	40	Kept in the village, generally not herded.
Njarniri	Small	Slaughter	Overwhelmingly male	95	5	Individually tied and zero-grazed; women's responsibility.
Bucal	Medium	Milk	Predominantly female	25	75	Individual ownership but commonly grazed on reserved pastures by paid herder or by family labour in rotation. Household milk supply. Most of village goats are in this group.
Bendi						Similar to *bucal*. Term used mainly by owners of hair sheep.
Horey	Large	Wool/ meat	Predominantly female	24	76	Main flocks which transhume. Reserve for constituting other groups as required. Milked by herders as required.

6. HERD AND FLOCK DEMOGRAPHY

With the exception of a relatively small number of animals owned purely as an investment, cattle are kept principally to provide milk for subsistence or draught power for agriculture (Figure 25). Minor functions of cattle are as drawers of carts, for lifting water from deep wells (especially in the north of the area), and to provide manure for fertilizing fields. Some transhumant groups use oxen as burden animals for the transport of people, personal effects and camp gear.

Small ruminants are kept primarily as a source of meat and as a ready source of cash. Macina sheep, however, also provide wool and milk (Section 5, Table 16), Maure sheep provide hair, and a large proportion of goats is milked at least some time in the course of a life cycle.

CATTLE POPULATION STRUCTURE

The age and particularly the sex composition of herds is regulated to a great extent by the main herd functions. Table 17 shows some typical herd structures in the different production subsystems of central Mali. Although the functions of these particular herds are known, in this case it would be possible to deduce the functions from the demographic structure alone. The high percentage of mature castrates in the two main cultivating groups is a result of the requirement for draught

Figure 25. *Work oxen ploughing a field in central Mali after the early rains.*

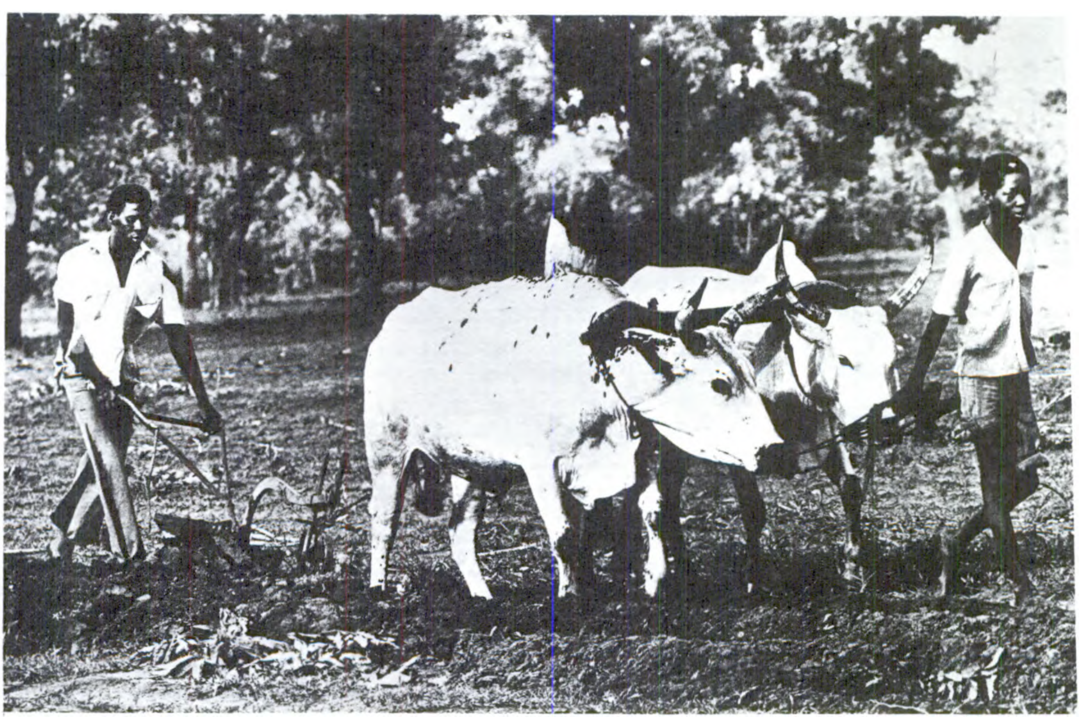


Table 17. *Cattle herd structures (%) in central Mali.*

Class of stock	Ethnic group, type of management and use					
	Bambara, sedentary, milk and draught	Mixed, sedentary, draught and milk	Fulani[a], transhumant, milk and transport	Fulani[a], transhumant, milk	Rimaibe, sedentary, milk and draught	Tuareg[a], nomadic, milk and transport
Males						
<1 year	5.6	7.2	9.9	9	15	16.3
1–3 years	8.5	9.3	12.5	6	13	9.3
>3 years	32.7	46.3	15.6	6	8	12.2
Total	46.8	62.8	38.0	21	36	37.8
Females						
<1 year	6.2	5.7	10.2	10	15	9.8
1–3 years	11.3	11.1	15.2	24	12	14.7
>3 years	35.7	20.2	36.1	45	38	37.6
Total	53.2	37.0	62.0	79	65	62.1
Castrates as % of total herd	32.3	43.4	9.3	4	7	12.9

[a] From Sangare (1983).

oxen. These herds are not, however, able to maintain themselves by recruitment from breeding, and draught animals have to be purchased from other ethnic groups.

In herds where milk is the major product (the detailed structure of such a herd is given in Figure 26), the proportion of breeding females is in the region of 40% of all animals: about two-thirds of these females, or a total of 25 to 27% of the herd, can be expected to be lactating at any one time. Even in the urban herds, which are generally considered to have milk as the primary output, these figures hold true (Table 18). It needs to be remembered that, where milk is a product, the milk taken for human consumption is at the expense of the calf, as no concentrates or substitutes are fed other than some coarse roughages. This practice has repercussions on calf growth and survival.

Oxen are usually trained to the plough and start work at about 4 years of age. It is possible that in both the millet and rice subsystems oxen are being kept to an age at which they are relatively inefficient producers of power. If this is the case (and Figure 27 provides some evidence that it is), it results from the extremely slow growth rate and late maturity of this class of stock, the difficulties in replacing them, particularly in recent years, and (even when supplied on credit) the amortisation cost. There will be a continuing demand for work oxen. The best means of satisfying this demand is probably to improve early nutrition to ensure entry into the work force at a younger age. This will result in either prolonging their working life or permitting their retirement at a younger age, giving better carcass quality. Whether limited feed resources should be devoted to this target or whether they should be used for breeding cows and currently working animals needs further study.

Fulani transhumant herds provide a reserve of mature male animals for transfer as draught animals to the neighbouring agropastoral systems. The herds of the latter, in particular those of the rice subsystem, have too few breeding cows whose fertility levels are too low to ensure herd stability. As a result mature draught animals must be purchased to maintain herd numbers and structure. Our assessment of the numbers of work oxen in the irrigated areas is in general accord with the returns of the Office du Niger although in some villages up to 70% of the cattle are recorded as work oxen and figures of 55% are not uncommon. Such an unbalanced herd structure has obvious repercussions on the stocking rate, and it is necessary for each head of cattle in the rice subsystem to be counted as 0.94 TLU and for each in the millet subsystem as 0.90 TLU. This compares with a 'normal' value for cattle herds of 0.73 TLU.

SMALL RUMINANT POPULATION STRUCTURE

As for cattle, the age and sex composition of small ruminant flocks is regulated by the main functions of the flocks, but to a considerably lesser degree.

Figure 26. *Population structure of a Fulani herd with milk as a primary function.*

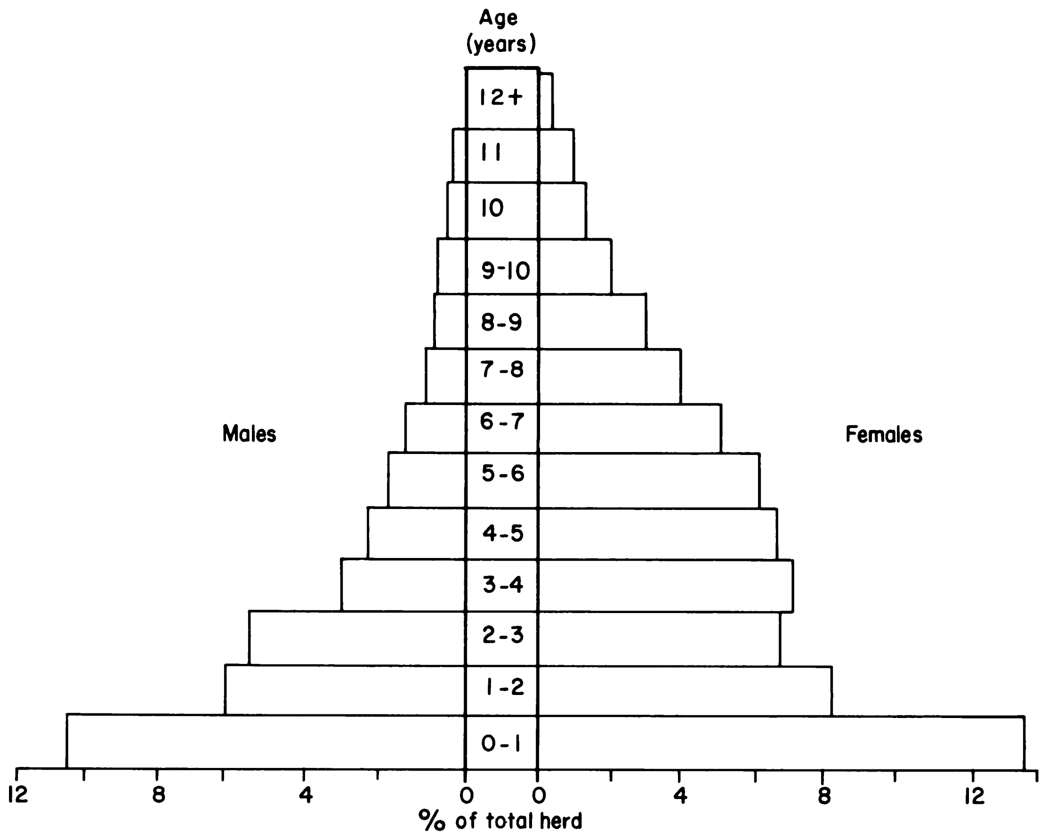


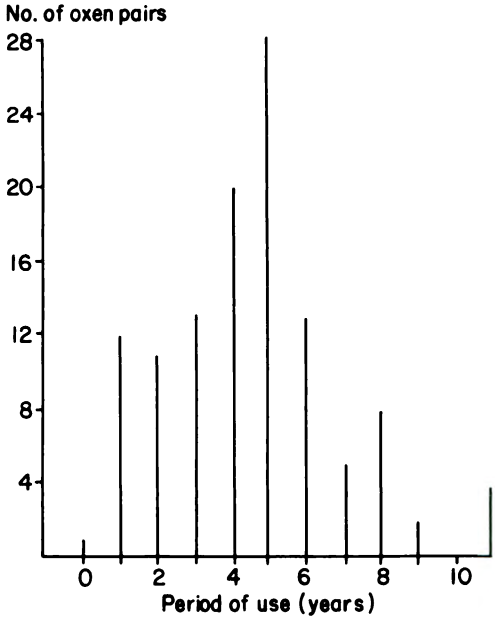
Table 18. *Age and sex structure of cattle populations in three urban areas in central Mali.*

Age (years)	Niono[a] (n = 588)		Ségou[b] (n = 901)		Mopti and Sevare[c] (n = 743)	
	M(%)	F(%)	M(%)	F(%)	M(%)	F(%)
<1	12.76	14.46	12.65	14.54	18.71	23.15
1–2	4.59	3.06	6.10	7.55	2.29	7.81
2–3	4.42	4.42	3.00	5.11	0.94	1.75
3–4	1.02	5.27	1.44	3.33	0.27	2.83
4–5	4.42	21.77	1.66	2.66	0.40	12.65
>5	4.59	19.22	7.77	34.18	2.02	27.19
Total	31.80	68.20	32.62	67.37	24.63	75.38

Sources: [a] Fayinke (1980); [b] Maiga (1980); [c] Ballo (1980).

Examples of flock structures in a number of central Malian societies are given in Table 19 for goats and in Table 20 for sheep. Male sheep and goats (whether entire or castrated) in general contribute about 25% of total numbers. Offtake of males (in addition, perhaps, to a higher death rate at very young ages) commences early, before 6 months of age in the better-managed flocks. In strict husbandry terms, males capable of breeding are in excess of the 2.5% actually required, but the possibilities of loss and of temporary sterility due to nutritional or disease stresses have to be considered. Moor sheep flocks have a ratio of breeding males to females of 1:13 while that of Fulani flocks is 1:15. For both these ethnic groups sheep provide wool as well as meat, and mature

Figure 27. *Distribution of oxen pairs by current working life in a central Malian village.*



entire males therefore contribute to flock economics in addition to fulfilling a breeding role. With the exception of the Tuareg nomadic flocks only in Fulani Macina sheep flocks do castrates contribute significantly to flock numbers – a further indication of the importance attached to wool production by the Fulani.

No comparative data on pre- and post-drought flock structures are available. This is unfortunate but it is probable that with the rapid rate of flock turnover and high levels of natality any effects would be of an ephemeral nature. With the exception of the structure of Macina flocks (Table 16) there was little evidence in central Mali of any system of flock stratification other than the short-term separation of kids and lambs from their dams at very young ages.

Table 19. *Flock structures of goats owned by some ethnic groups in central Mali.*

Ethnic group	Management system	Total no. of animals	Males (%)				Females (%)			
			Total	>14 months	<14 months	Castrates	Total	>14 months	<14 months	Breeding[a]
Tuareg[b]	Pastoral/nomadic	648	21.0	11.4	9.6	5.4	79.0	66.0	13.0	70.3
Tuareg	Pastoral/transhumant	702	26.2	5.6	20.6	5.0	73.8	46.8	27.2	55.9
Fulani[b]	Pastoral/transhumant	569	21.0	6.3	14.7	4.0	79.0	60.4	18.6	66.6
Fulani[c]	Agropastoral/transhumant	346	28.6	7.8	20.8	8.1	71.4	49.7	21.7	56.9
Moor	Pastoral/transhumant	682	20.2	3.4	16.8	1.2	79.8	51.8	28.0	59.1
Bambara	Agropastoral/sedentary	926	24.9	5.5	19.4	3.6	75.1	52.8	22.3	60.2

[a] Females older than 10 months.

[b] Peacock (1983).

[c] Fulani agropastoralists in the Niger inundation zone own also Macina sheep.

Table 20. *Flock structures of sheep owned by some ethnic groups in central Mali.*

Ethnic group	Management system	Total no. of animals	Males (%)				Females (%)			
			Total	>15 months	<15 months	Castrates	Total	>15 months	<15 months	Breeding[a]
Tuareg[b]	Pastoral/nomadic	933	26.4	12.3	14.1	14.0	73.6	52.3	21.3	63.5
Tuareg	Pastoral/transhumant	667	27.4	6.8	20.6	5.0	72.9	46.7	26.2	61.7
Fulani[b]	Pastoral/transhumant	215	29.8	7.5	22.3	5.1	70.3	46.5	23.8	60.5
Fulani[c]	Agropastoral/transhumant	4 543	25.5	10.2	15.3	11.2	74.5	45.3	29.2	63.3
Moor	Pastoral/transhumant	1 045	22.9	6.9	16.0	6.2	77.2	51.5	25.7	66.0
Bambara	Agropastoral/sedentary	241	23.5	2.0	21.5	2.1	75.5	45.4	30.1	62.4

[a] Females older than 10 months.

[b] Peacock (1983).

[c] Fulani agropastoralists in the Niger inundation zone own also Macina sheep.

PART TWO

CATTLE PRODUCTIVITY

7. REPRODUCTIVE PERFORMANCE

AGE AT FIRST CALVING

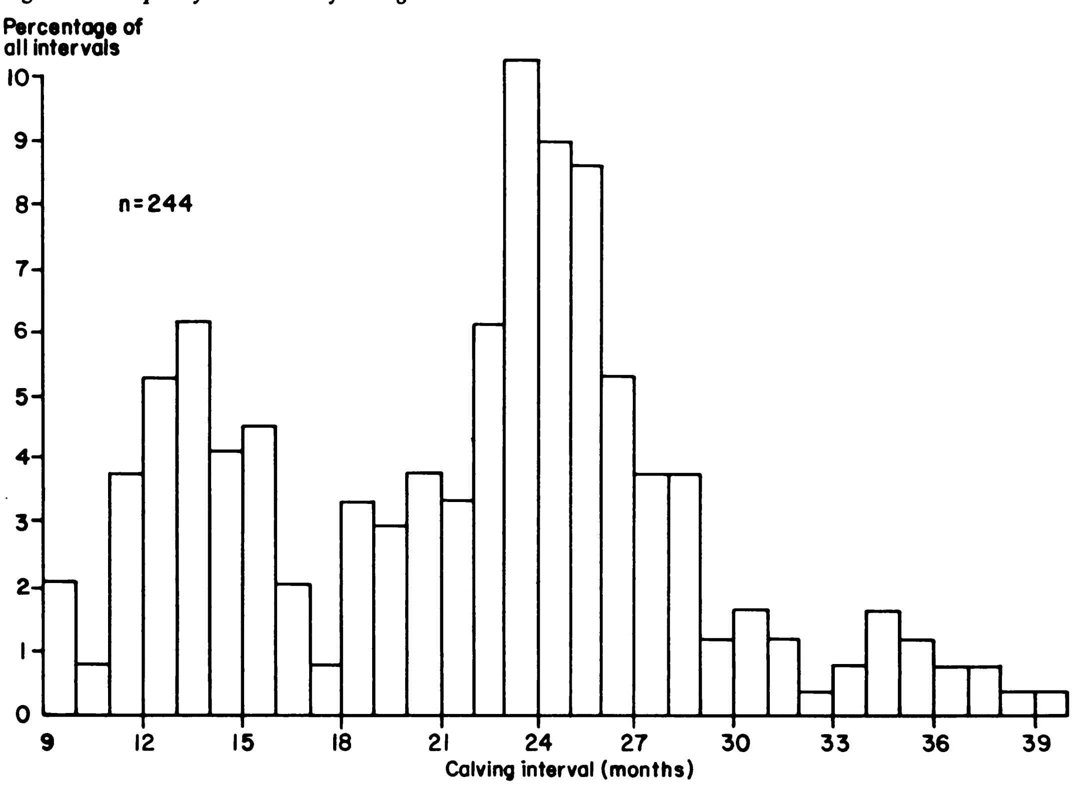
A total of 20 heifers whose date of birth was known had themselves given birth by the end of the study. The mean age at first calving of these animals was 1505 ± 103.3 days (49.5 ± 3.34 months).

CALVING INTERVAL

The observed calving interval ($\bar{x}$ ± s.d.) was 665 ± 202.2 days (n = 244) or just under 22 months, the coefficient of variation being 30.3%. As can be seen from Figure 28, there is a distinct bimodal pattern to the distribution of these intervals with peaks at 12 to 16 months and at 23 to 26 months, and some indications of a third minor peak at around 36 months.

The analysis of variance of this trait (Table 21) demonstrates that parity (i.e. dam's age) significantly affected the length of the next parturition interval. The least-squares means for the main variables affecting calving interval are given in Table 22. The observed sample mean (665 days) differs somewhat from the computed overall least-squares mean (644 days) as the latter is adjusted for the unequal subclass numbers. The general

Figure 28. *Frequency distribution of calving intervals in cattle.*



trend appeared to be one of reducing interval with increasing parity until older ages were reached when the interval between calvings increased sharply. There was a clearly longer interval after the birth of a male calf than after that of a female. Month of birth had a considerable but non-significant effect on the subsequent parturition interval, which ranged from a minimum of 565 days after a January calving to a maximum of 723 days after a post-rains calving in October and November. There were also considerable though non-significant differences between herds within each of the two subsystems.

Table 21. *Analysis of variance of calving interval for agropastoral cows in central Mali.*

Source of variation	d.f.	MS x 10^{-3}
System	1	109
Month	11	21
Parity	4	142**
Sex	1	46
Herd (millet)	3	40
Herd (rice)	4	21
Remainder	220	40

**P<0.01.

Table 22. *Least-squares means for calving interval of agropastoral cows in central Mali.*

Variable	n	$\bar{x}$ (days)	± SE
Overall	244	644	18
System			
Millet	104	617	26
Rice	140	671	21
Parity			
1	772	646a	29
2	47	602a	33
3	32	654ab	39
4	39	585a	34
'9'	54	734b	32
Sex			
Female	136	630	21
Male	108	659	24

Note: '9' are births of unknown parity assumed to be ≥3.

Within variable groups, means followed by different letters differ significantly (P<0.05). Variable groups without any letters did not show a significant difference in the analysis of variance.

When the age at death of a calf was introduced as a covariant, the subsequent parturition interval was lengthened significantly (t = 2.68, P = 0.011) for each day of survival of the calf, the relationship being:

Parturition interval = 499.5 + (age at calf death x 0.318) days

The repeatability (± SE) of the 244 intervals for a total of 166 cows was 0.182 ± 0.0138.

SEASON OF CALVING

The monthly distribution of 452 calvings (relating to all animals born in completed years of the study) is shown in Figure 29 which also shows the season of conception, assuming this occurred approximately 9 months previously. Some 56% of all calves were conceived during the 3-month period of the rains.

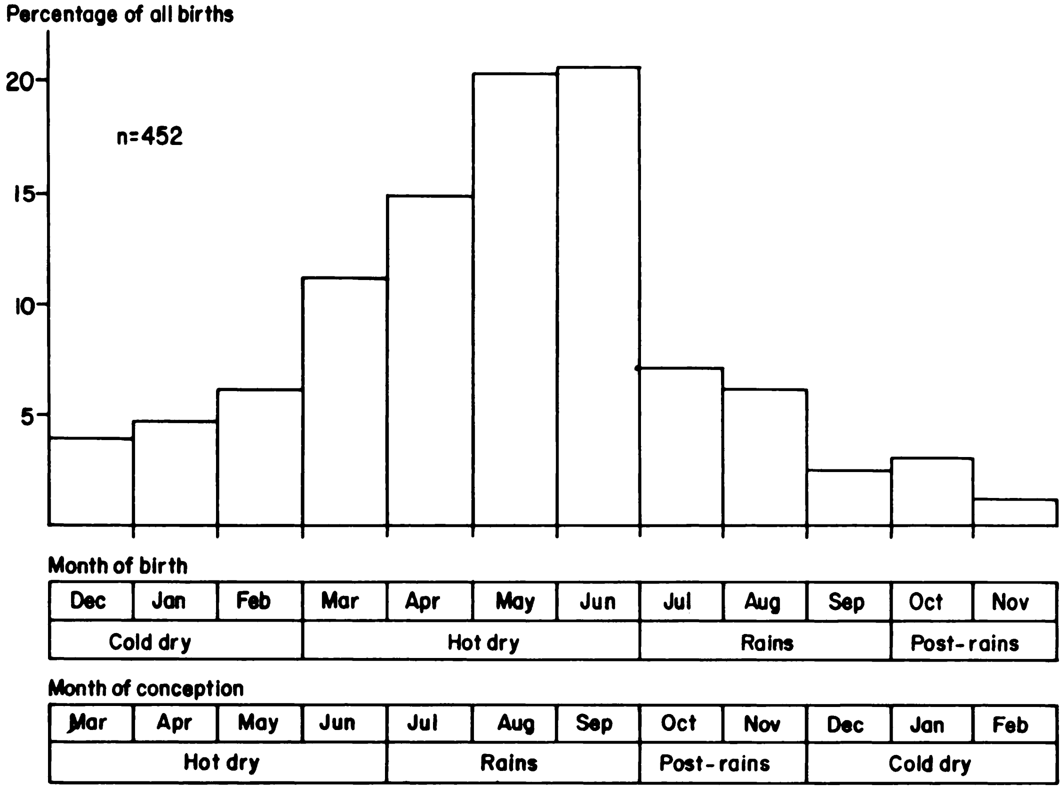
When correlation coefficients were calculated for the number of births per month and rainfall 9 and 10 months previously, there were highly significant correlations (respectively r = 0.562 and 0.563, d.f. = 70, P<0.001) for the pooled data over 6 years. Correlations were significant for rainfall both 9 and 10 months earlier for individual years. Correlations between rainfall 11 and 12 months previously and the number of calves born were not significant. Details of these coefficients and significance levels are given in the Appendix.

NUMBER OF CALVES BORN PER BREEDING FEMALE IN THE HERD

Reconstruction of cow histories (by observation and by questioning of owners for cow calving data before the study began) indicated that the 274 cows in the study which had calved at least once had given birth to a total of 797 calves. Cows having given birth to one to eight calves respectively accounted for 23.0, 21.2, 23.7, 16.1, 10.9, 1.8, 1.8 and 1.5% of all cows, the average number of calves born per cow being 2.91. Numbers of calves born to those cows still in the herds (i.e. whose reproductive careers were still in progress) at 30 June 1984 are shown in Figure 30: the average number born to each of these animals was 3.02.

There is a slight anomaly in these calculations due to assuming that the first calf of mature cows of unknown history is the third for that animal. However, changing this to four would hardly affect the general conclusion that very few cows bear more than five calves. The average lifetime production is of the order of three calves per cow. Most cows therefore either died or were culled from the herd at about 9 years of age (this being age at first parturition + interval to second calf + interval to third calf + time of weaning third calf).

Figure 29. *Seasonal distribution of conceptions and calvings for cattle in central Mali.*



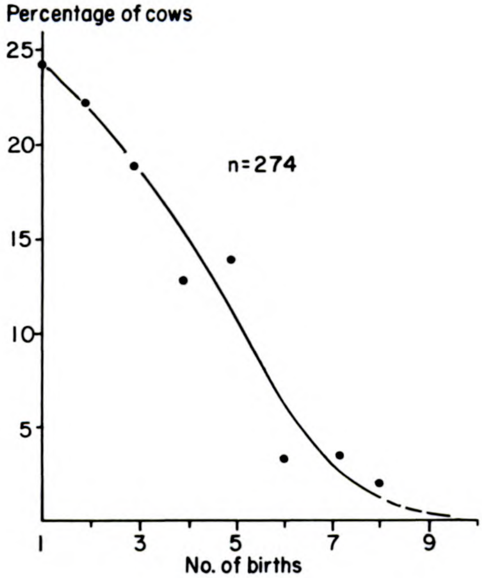
DISCUSSION

It has been suggested that indigenous cattle in the tropics normally drop their first calf at 3 to 4 years of age (Mahadevan, 1966). Under improved management where seasonal nutritional stress can be reduced, it is indeed possible to achieve first calving at 43 months. This has been the case at Niono on the government research station (ILCA/IER, 1978) under exactly the same climatic conditions as pertained in this study. Nonetheless, even under these improved conditions, in series of bad rainfall years or when supplementary feed supplies could not be provided, age at first calving was delayed. Traditional owners in the dry areas of Africa have, for many years, complained of delayed first calvings due to "lack of fodder resources" – although they do not always associate this lack with overstocking in general. There has been to date little empirical evidence for this assertion, but the firm data on age at first calving from 20 heifers in this study support the view that first parturitions do not generally occur until the beginning of the fifth year of a cow's life.

The calving interval of 665 days is equivalent to an approximate calving rate of 55% (365 x 100/665). In Sudan, under similar climatic conditions, a rate of 40% was calculated for sedentary cattle, this improving to 65% for migratory cattle where nutritional stresses could be expected to be mitigated to some extent (Wilson and Clarke, 1976a). Based on questionnaire surveys rather than on observation, estimated rates for other sedentary cattle in Mali are 55% (Coulomb, 1970). Rates of 60% (Coulomb, 1971) and 63% (Wilson and Wagenaar, 1983) for transhumant cattle have been calculated from questionnaire data collected in Niger. Where nutritional stresses are reduced by research station management, calving intervals can be progressively reduced – at Niono, for example, from 561 to 423 days from 1966 to 1973 (ILCA/IER, 1978).

The effects of year were not obtained during this study and month of calving had no significant effect, possibly because of the generally long calving interval. However, the general effect of month of calving was that which would be expected if nutrition were the major factor in reproductive rate. Thus a calving in the cold dry season allowed conception during the next rainy season, leading to shorter intervals than the mean. The effect of parity was also as expected since older, weaker cows took longer to recover from pregnancy and lactation stress, this resulting in longer intervals. The effect of the sex of the calf is inter-

Figure 30. *Number of calves born per cow in central Malian herds.*



esting, male calves apparently delaying conception by putting more strain on cows. A similar calf sex effect has been observed in red deer in Scotland (Clutton-Brock et al, 1982) where calving intervals 11 days longer after males were attributed to longer gestation intervals, heavier calf weights and more frequent and more intensive suckling by male calves. The effect of the age at death of the calf on calving interval can be attributed to the suppression of lactation anoestrus.

The repeatability of 0.182 is better than the average of all published data for this trait in tropical cattle, calculated as 0.131 by Payne (1970). It is as good as, or better than, other African records: 0.05 for Northern Sudan Zebu (Alim, 1964) and 0.09 to 0.18 for the Small East African Zebu (Mahadevan et al, 1962). However, it is still a relatively low value and it is more than likely that the observed variation is due to environmental rather than hereditary additive factors. Seeking improvement of this trait through breeding would therefore appear to have little chance of success, at least until better control of the external environment is achieved.

Nutritional effects on the reproductive pattern are clearly demonstrated in the seasonality of calving (Figure 29). The results obtained in this study confirm other observations made in dry northern Africa. In Sudan, 62.5% of all calves were born in the period April to June (Wilson and Clarke, 1976a). In Niger, owners reported that 40% of calves dropped in May and August (Coulomb, 1971) and in a recent survey, also in Niger, 57% of calves were born in July to September (Wilson and Wagenaar, 1983). This phenomenon is not confined to dry northern Africa but occurs also in southern Africa, where breeding restrictions are not practised and where rainfall is seasonal. In Swaziland, both Brown (1959) and Butterworth (1983) have reported marked seasonality in calving. The latter author found a normal unimodal curve of calf births, with 57% and 55% of the annual total occurring in October to December in the High Veld and Middle Veld respectively. The values of r in Butterworth's study, which included 7 years' data, were 0.89 and 0.83 for rainfall 10 and 11 months previously, and 0.74 for 9 months previously. Reproductive response in the current study, which probably occurred even before the onset of weight gain, was thus more rapid than in Swaziland.

Additional evidence that nutrition is the major constraint to reproduction in the traditional environment comes from the bimodal distribution of calving intervals shown in Figure 28, with those cows failing to conceive in the first rainy season not conceiving until the next. This pattern has also been observed in Niger where 38% of calving intervals were around 11 to 13 months and 24% around 24 to 25 months: there were no intervals at 19 and 20 months and only one at 18 months (Wilson and Wagenaar, 1983).

Poor nutrition is in large part responsible for the low average number of calves born to cows in the herd. The average of 2.9 calves per cow results from late first parturitions, long calving intervals and early exhaustion of the body reserves leading to an early culling age. Cows are unproductive for long periods of their life but continue to consume natural fodder resources, thus further aggravating an already critical feed supply situation. Improved fodder production or better utilisation of existing production would do much to reduce nutritional stress, particularly in the dry season, and thus improve the reproductive rate.

8. GROWTH AND WEIGHT

BIRTHWEIGHT

The observed birthweight ($\bar{x} \pm$ s.d.) of 107 calves born during the 1978–1984 period was 16.6 ± 2.67 kg. The analysis of variance of this trait (Table 23) demonstrates that only parity (i.e. dam's age) has any significant effect. The least-squares means for all the variables considered are shown in Table 24.

GROWTH TO MATURITY

For cattle of known birth date, a generalised growth curve to 4 years of age is shown in Figure 31. Analyses of variance and least-squares means for weights at various ages are shown in Tables 23 and 24 respectively. The observed sample means used in Figure 31 differ somewhat from the computed least-squares means shown in Table 24, as these last are adjusted for the unequal subclass numbers. The season of birth had a highly significant effect on growth throughout the life of the animal to its maturity (Figure 32). The year of birth also had consistent significant effects on weight at all ages (except birth) up to 9 months of age. Among herds, differences in growth rate were also significant. Coefficients of variation for weights at various ages were: 30 days, 20.00%; 90 days, 20.63%; 180 days, 19.98%; 210 days, 19.16%; 270 days, 18.49%; 365 days, 18.43%; 550 days, 17.06%; 730 days, 16.43%; and 1095 days, 14.55%. Phenotypic correlations between calf weights at different ages are shown in Table 25.

Cows did not reach final mature weights until after 5 years of age. Mature weights were 230.4 kg in the rainfed millet subsystem and 224.5 kg in the rice subsystem. Males – exemplified in this study by work oxen in the irrigated subsystem – had average mature weight of 297.2 kg at ages above 6 years, although the largest individuals weighed up to 430 kg.

BREEDING FEMALE POSTPARTUM WEIGHT

The observed postpartum weight ($\bar{x} \pm$ s.d.) was 214.7 ± 33.63 kg with a coefficient of variation of 13.04%.

The mean squares from the analysis of variance are set out in Table 26 which shows that parity, season and year exerted highly significant effects on postpartum weight while differences among herds were also significant in both rainfed and irrigated subsystems. The least-squares means for postpartum weights are given in Table 27 while graphic representations of the main variables affecting this parameter are shown in Figure 33.

The postpartum weight was reduced by 0.016 kg for each day of reduction to the previous parturition, this effect being non-significant.

EFFECTS OF CLIMATE ON GROWTH AND MATURE WEIGHT

Growth curves for calves born during the main calving season in each year from 1978 to 1982 are shown in Figure 34. The figure clearly shows the effects of the fluctuating feed supply on the overall development of weight over medium- to long-term periods.

The weight of mature oxen fluctuated from 88.9 to 107.2% of their mean weight when weights were pooled over two-monthly periods (Figure 35). When weights for single months were used, the minimum early July weight (240.5 kg) was found to be only 72.5% of the maximum weight of 331.9 kg in November. Similar ranges of variation were found for all ages of breeding females, reinforcing the picture shown in Figure 34. Adult females with four pairs of incisors varied from 87.7 to 110.2% of their mean weight.

The most perturbing long-term effect is shown in Figure 36, supported by the data in

Table 23. *Analysis of variance of cattle weights at specified ages.*

Source of variation	Birth		30 days		90 days		180 days		210 days		270 days		365 days		550 days		730 days		1095 days	
	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS
System	1	2.25	1	17.8	1	66.5	1	88.6	1	61.6	1	25.4	1	3.5	1	0.2	1	259.1	1	186.0
Sex	1	1.73	1	2.2	1	13.3	1	77.4	1	14.1	1	35.5	1	107.5	1	67.1	1	789.4	1	1 547.0
Parity	3	13.42*	3	20.0	3	70.6	3	292.1	3	193.3	3	284.0	3	684.8*	3	553.1	3	1 128.6*	3	1 481.4
Season	1	3.54	3	251.1***	3	610.5***	3	3 059.7***	3	2 241.7***	3	1 223.0***	3	508.4*	3	2 465.5***	3	2 024.9***	3	3 419.6***
Year	4	7.03	6	72.9**	4	248.1**	4	604.3**	4	764.5***	2	523.4*	4	286.5	4	280.4	4	1 131.0*	3	1 262.4
Herd/millet	3	28.99**	3	18.2	3	115.9	3	380.8*	3	562.0**	3	592.8*	3	328.8	3	634.9	3	236.7	2	88.5
Herd/rice	4	16.28*	4	9.9	4	90.7	4	150.1	4	330.1	4	865.4***	4	549.1*	4	1 155.8*	4	860.5	4	2 523.2**
System x Season	–	–	3	22.6	3	167.3	3	270.9	3	155.8	3	56.0	3	364.1	3	169.2	3	69.7	3	47.0
Sex x Season	–	–	3	50.3	3	53.6	3	102.2	3	19.3	3	56.4	3	312.4	3	29.4	3	365.5	3	810.6
Error	88	5.07	167	24.3	310	62.6	328	135.5	328	143.9	305	159.7	260	189.6	211	349.3	161	370.3	82	559.0

***P<0.001; **P<0.01; *P<0.05.

Table 24. ***Least-squares mean weights (kg) for agropastoral cattle at different ages.***

Variable	Birth		30 days		90 days		180 days		210 days		270 days		365 days		550 days		730 days		1095 days	
	n	x̄	n	x̄	n	x̄	n	x̄	n	x̄	n	x̄	n	x̄	n	x̄	n	x̄	n	x̄
Overall	107	17.73	295	26.26	336	38.19	354	52.20	354	56.76	331	64.01	286	74.36	237	102.75	187	123.18	106	175.39
System																				
Millet	53	17.93	132	25.73	138	37.33	144	51.22	142	55.92	131	62.46	115	74.14	100	102.69	80	120.93	40	172.06
Rice	54	17.53	163	26.79	198	39.05	210	53.18	212	57.61	200	64.57	171	74.57	137	102.79	107	125.43	66	178.71
Sex																				
Female	58	17.59	164	26.43	189	38.56	198	53.09	197	56.33	187	64.69	159	73.14	133	101.82	106	119.70	61	167.33
Male	49	17.87	131	26.09	147	37.82	156	51.31	157	57.19	144	63.32	127	75.58	104	103.68	81	126.66	45	183.44
Parity																				
1	25	17.39ab	82	25.61	93	37.15	93	50.66	93	54.68	83	62.43	68	71.70a	63	98.92	50	166.98a	26	183.44
2	22	18.60a	54	26.64	65	38.60	71	54.47	73	58.46	68	66.72	58	77.83b	45	104.90	30	122.56ab	16	178.12ab
3	14	18.10ab	41	26.11	46	39.54	53	53.24	52	57.14	49	62.24	45	71.08a	39	101.68	37	121.72ab	22	171.28a
'9'	46	16.83b	118	26.69	132	37.47	137	50.53	136	56.77	131	64.66	115	76.82b	90	105.50	70	129.99b	42	185.16b
Season																				
Cold dry	15	17.24	36	24.14a	47	33.81a	47	46.89a	47	54.37a	47	68.10ab	43	79.05a	33	102.25a	29	135.15a	21	187.00ac
Hot dry	80	17.54	223	23.94a	233	38.82b	243	61.19b	244	65.38b	228	69.66a	196	73.89b	166	113.69b	131	118.37b	72	162.48b
Rains	12	18.41	27	29.72b	44	43.21c	44	56.97c	53	57.54a	53	59.78c	37	69.48b	27	104.98a	16	105.75b	7	153.29ab
Post-rains	14		9	27.23ab	12	36.93ab	11	43.76a	10	49.75a	10	58.51bc	10	75.00ab	10	390.08ab	11	133.44a	6	198.77c
Year																				
1978	–	–	6	24.17a	–	–	–	–	–	–	–	–	–	–	10	100.96	10	138.66a	9	182.12
1979	–	–	9	31.83b	22	39.39ab	28	48.98ac	27	52.98a	26	61.32a	26	77.78	25	104.68	21	120.31b	17	178.05
1980	14	18.62	39	25.51a	52	37.36a	81	52.67ab	89	56.77ab	90	63.30a	90	72.26	79	102.93	76	114.85b	56	163.95
1981	24·	18.13	71	26.69a	81	39.12ab	80	55.20b	78	60.60b	76	68.63b	74	76.73	62	99.56	56	121.88b	24	177.63
1982	32	17.60	79	25.26a	94	35.69a	84	48.93c	81	53.31a	78	61.73a	71	73.79	61	105.62	24	120.19b	–	–
1983	24	16.83	81	26.42a	87	40.39b	81	55.22b	79	60.15b	61	65.09a	25	71.23	–	–	–	–	–	–
1984	13	17.46	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Herd/millet																				
5	4	18.16ab	13	25.86	16	35.73	20	55.58a	20	62.48a	17	68.30a	14	77.18	10	108.43	6	128.40	4	177.81
7	4	21.52a	12	24.05	10	35.42	16	44.76b	16	48.48b	16	53.82b	15	67.81	9	90.26	7	112.13	–	–
8	27	16.58b	71	26.31	74	40.02	73	53.59a	73	57.40a	68	65.25a	58	73.37	56	107.85	47	121.43	27	169.55
15	18	15.45b	36	26.69	38	38.13	35	50.94ab	33	55.30ab	30	66.47a	28	78.19	25	104.22	20	121.76	9	168.83
Herd/rice																				
53	12	15.41a	45	26.80	56	37.01	63	51.31	63	57.28	62	65.01a	59	76.25ab	48	95.15a	34	126.40	22	168.80ac
60	16	18.66b	34	27.07	41	40.08	46	53.97	46	58.61	44	64.47ab	35	70.42b	28	100.60ab	25	119.13	15	178.18abc
64	15	17.34ab	39	26.29	50	39.21	52	51.19	56	53.65	50	57.65b	45	71.09b	36	96.19a	25	116.42	14	153.75c
67	4	18.70b	25	26.08	29	37.95	27	56.05	25	62.02	23	72.13a	17	82.24a	13	106.53ab	11	130.69	9	190.80ab
89	7	17.54ab	20	27.72	22	41.02	22	53.47	22	56.48	21	63.56ab	15	72.87ab	12	115.53b	11	134.47	6	202.03b

Within variable groups, means followed by different letters differ significantly ($P<0.05$). Variable groups without any letters did not show a significant difference in the analysis of variance.

Figure 31. *Generalised growth curve to 4 years of age for cattle of known birth date.*

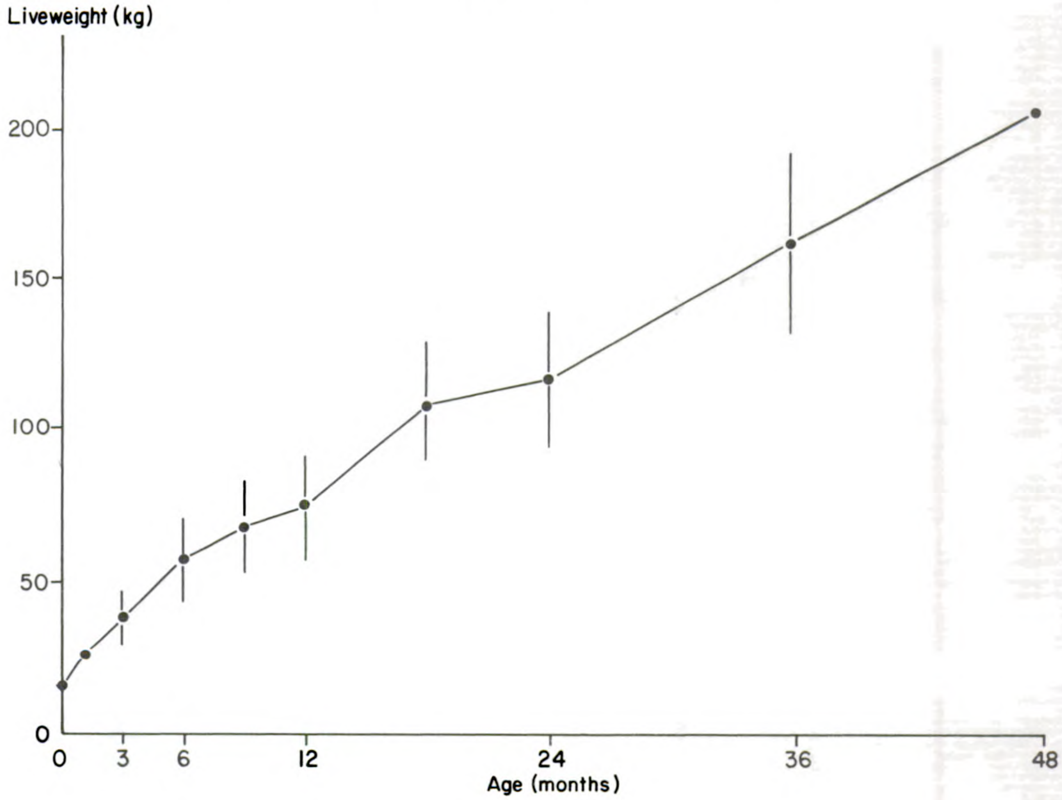


Table 28. The poor rainfall (in relation to the long-term mean) encountered at the beginning of the study period has continued and even been aggravated. As a result, the mean mature weight of work oxen fell by about 1.4 kg per month over the whole period. Similar, although less spectacular, losses were recorded in mature females.

DISCUSSION

Growth rates were very slow, averaging only 185 g/day from birth to presumed weaning at 7 months of age. From this age to 1 year growth slowed even further to an average of only 121 g/day. This period corresponds to postweaning and, for the majority of calves born during the late hot dry season, would coincide with the worst period of the year from February or March through to May or June. In fact, calves born during the hot dry season had a postweaning gain of only 59 g/day compared with 174 g/day gained by those few calves that were born in the post-rains season and thus benefitted from the following year's rainy season during their postweaning period.

As can be seen from Figure 32, the significant effects of season of birth on growth were not only marked but followed a logical pattern related to suckling and then to the availability of fodder right up to the age of 2 years.

Although between- and among-year effects were significant up to 9 months of age, there was no clear relationship with total annual rainfall for the year in question. It is probable that the pattern of rainfall within the season and variation in management practices between years masked any direct effects. System did not exert a significant influence on growth but except at birth, cattle in the irrigated rice subsystem were consistently heavier than their contemporaries in the rainfed subsystem up to adult weights. Males were lighter than females after weaning, this probably indicating that slightly more care was given to female calves or that less milk was removed for human consumption from dams of female calves. From 1 year of age onwards males continued to be heavier than females, with an advantage of 3.0% at 1 year, 6.0% at 2 years, 10% at 3 years, 17% at 4 years and 32% at mature weights. Differences in weight between the sexes were not significant up to 3 years of age.

The significant differences in weight which occurred among herds have not yet been

Figure 32. *Relationship between season of birth and growth of cattle to 3 years of age.*

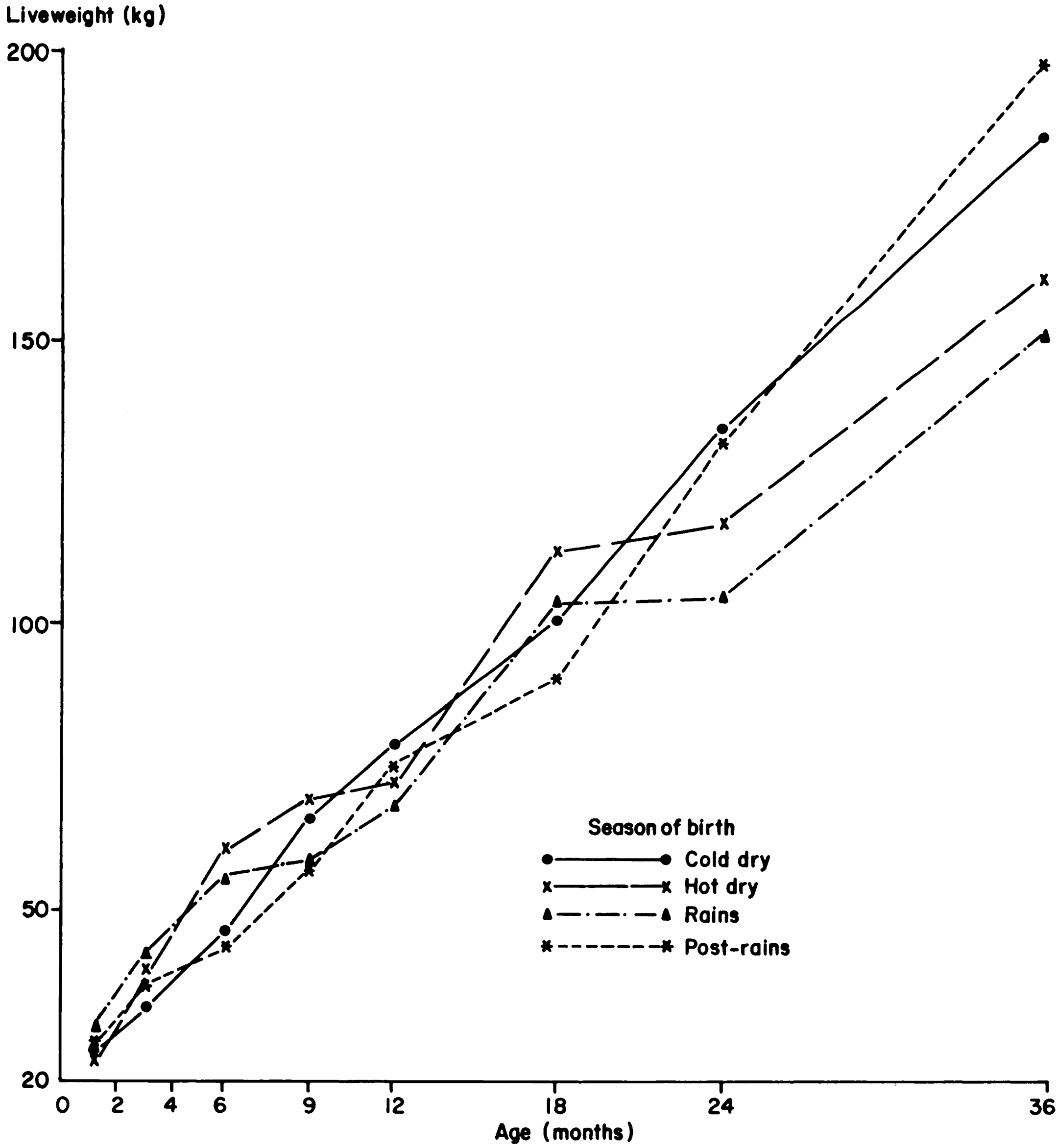


Table 25. *Phenotypic correlations between calf weights.*

Age (days)	Age (days)								
	30	90	180	210	270	365	550	730	1095
30	1.00	0.47	0.01	0.14	0.20	0.23	0.16	0.38	0.37
90		1.00	0.31	0.25	0.04	0.04	0.31	0.26	0.15
180			1.00	0.91	0.74	0.46	0.62	0.38	0.37
210				1.00	0.86	0.67	0.61	0.52	0.51
365						1.00	0.44	0.66	0.72
550							1.00	0.62	0.51
730								1.00	0.75
1095									1.00

Table 26. *Analysis of variance of postpartum weights of dams.*

Source of variation	d.f.	MS
System	1	797.73
Sex	1	857.92
Parity	3	19 354.09***
Season	3	10 286.64***
Year	6	6 433.46***
Herd/millet	3	3 282.96**
Herd/rice	4	2 812.88**
Error	414	783.95

***P<0.001; **P<0.01.

explained in terms of the differing management practices or individual abilities of the owners or herders.

There is an absence of a clear inflection point in the growth curve in early life. Indeed, growth rates from 1 to 2 years at 134 g/day and from 2 to 3 years at 143 g/day exceeded the postweaning gain to 1 year of 121 g/day. Calves and growing stock obviously suffered severely from poor nutrition. In the rice subsystem, the probably slightly better feed situation was offset by heavier parasite burdens, especially by liver flukes (Traoré, 1984).

Postpartum weights in general followed the pattern that could be expected for parity and season. Primiparous cows weighed approximately 202 kg, compared with a mean weight of 192 kg for all females at 1460 days. This weight, obtained from a much larger sample (n = 107) than the small number (n = 20) of animals whose age at first calving was known for certain (Section 7), adds firmly to the hypothesis that first calving generally occurs at just over 4 years of age. The present main calving season is in the late hot dry season, this having repercussions on cow weight (and therefore ability to survive and supply milk) as well as the postweaning growth of calves, as already noted.

The low and diminishing rainfall over the 7-year study period (1984 weights were included in this analysis) resulted in a long-term and apparently sustained reduction in postpartum weights. Weights for the years 1982 to 1984 inclusive were all below the 7-year mean, the lowest being 4.7% below the overall average and 12.5% below the maximum weight observed in 1980.

Seasonal effects were evident not only on growth rates but also on the intra-annual change

Table 27. *Least-squares means for postpartum weights (kg) of dams.*

Variable	n	$\bar{x}$	± SE
Overall	433	222	2.73
System			
Millet	192	220	3.28
Rice	241	223	3.06
Sex of calf			
Female	231	223	3.07
Male	202	220	3.05
Parity			
1	107	202a	3.67
2	86	227b	3.85
3	59	227b	4.42
'9'	181	231b	3.00
Season			
Cold dry	69	220a	3.83
Hot dry	283	209b	2.49
Rains	64	232c	4.08
Post-rains	17	227ac	7.15
Year			
1978	15	227abc	7.78
1979	31	227a	5.52
1980	97	238b	3.50
1981	85	222a	3.63
1982	106	216c	3.53
1983	85	212c	3.68
1984	14	215c	7.97
Herd/millet			
5	23	217ab	6.48
7	25	218a	6.31
8	88	215a	3.65
15	56	232a	4.30
Herd/rice			
53	78	213a	3.82
60	52	219ab	4.58
64	57	225ab	4.47
67	31	232b	5.61
69	23	228b	6.37

Note: '9' are dams with known parities ≥4 and unknown parities ≥3.

Within variable groups, means followed by different letters differ significantly (P<0.05). Variable groups without any letters did not show a significant difference in the analysis of variance.

in weight of cattle within specified age groups (Figure 35), including those under 4 years of age which should still be actively growing. In addition to the effects on reproductive performance and overall output of breeding females, the consequences are serious for other aspects of agropastoral operations. Work oxen enter the cultivation season in very low condition. Compensatory recovery in weight is further delayed in this class of stock as they have little time for grazing during the period of agricultural operations and are not, in general, given adequate high-energy supplementation to satisfy their needs.

The long-term decline in mature weight (Figure 36) is seen to be correlated, at least in part, with a similar decline in the amount of rainfall. Mature weights of oxen were lower by about 80 kg at the beginning of 1984 compared with the initial weights in 1978, this decline being equivalent to about 4% per year. In cows, while absolute weigh changes were less than for oxen – 40 kg lighter (2.7% per year) in the rice subsystem and 27 kg lighter (1.8% per year) in the millet subsystem – the consequences on productivity are likely to be more serious. These long-term changes in individual body weight are a result not only of the reduced rainfall leading to lower fodder availability, but also of a probable increase in cattle numbers over the study period. These weight changes do not appear to have resulted, so far, in decreased calving rates or increased mortality, but the time cannot be far distant when these will occur.

Figure 33. *Relationships between postpartum weights of cattle and parity, season and year of calving.*

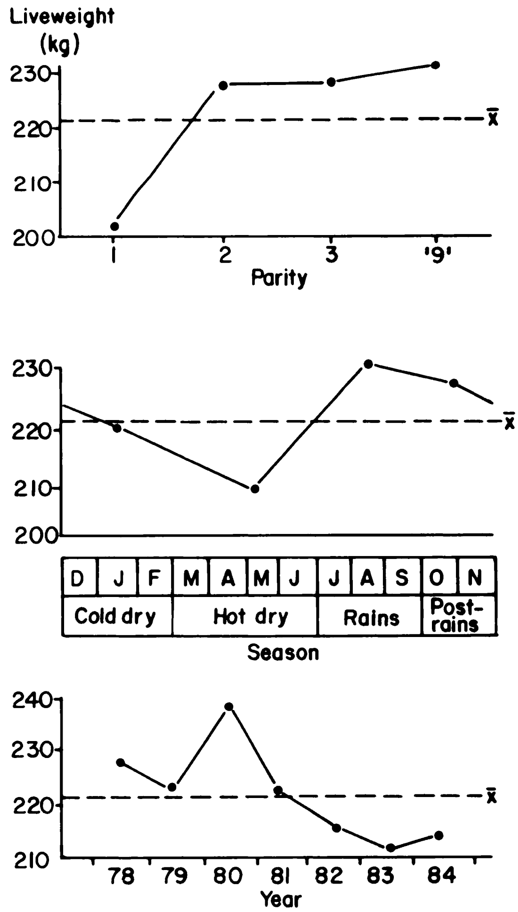


Figure 34. ***Long-term growth patterns for calves born in May each year from 1978 to 1982.***

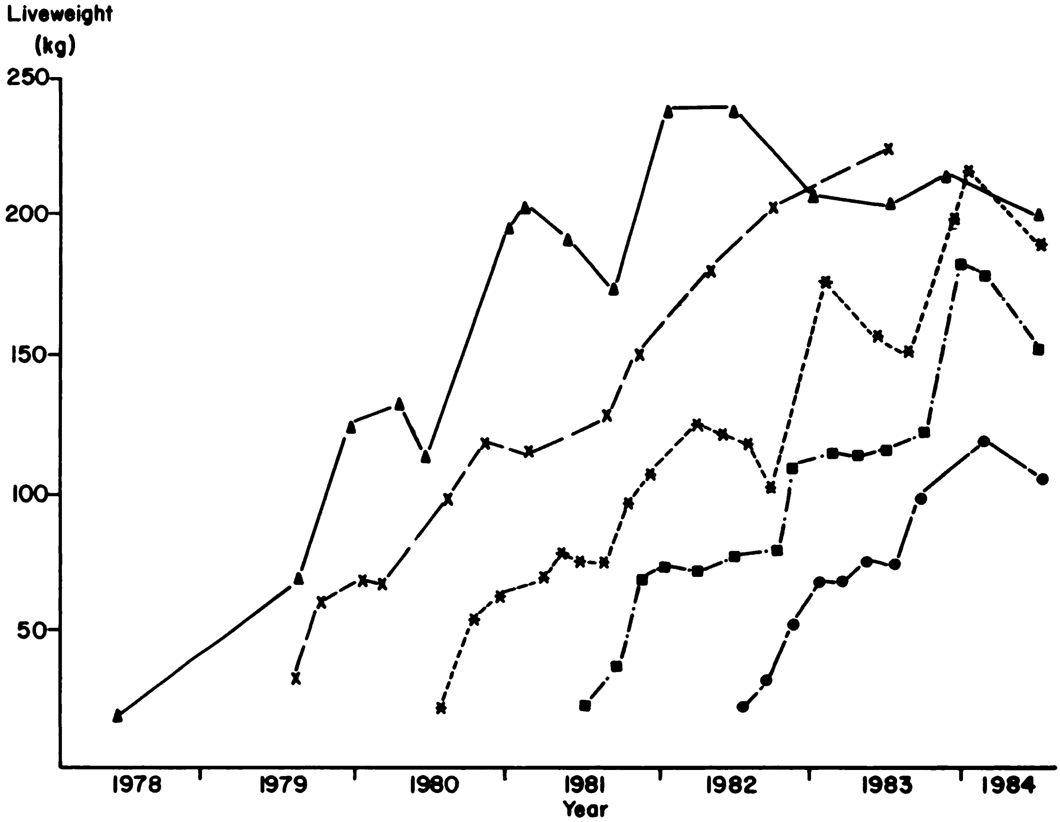


Figure 35. *Seasonal weight changes in mature oxen and female cattle with 1, 2, 3 and 4 pairs of permanent incisors.*

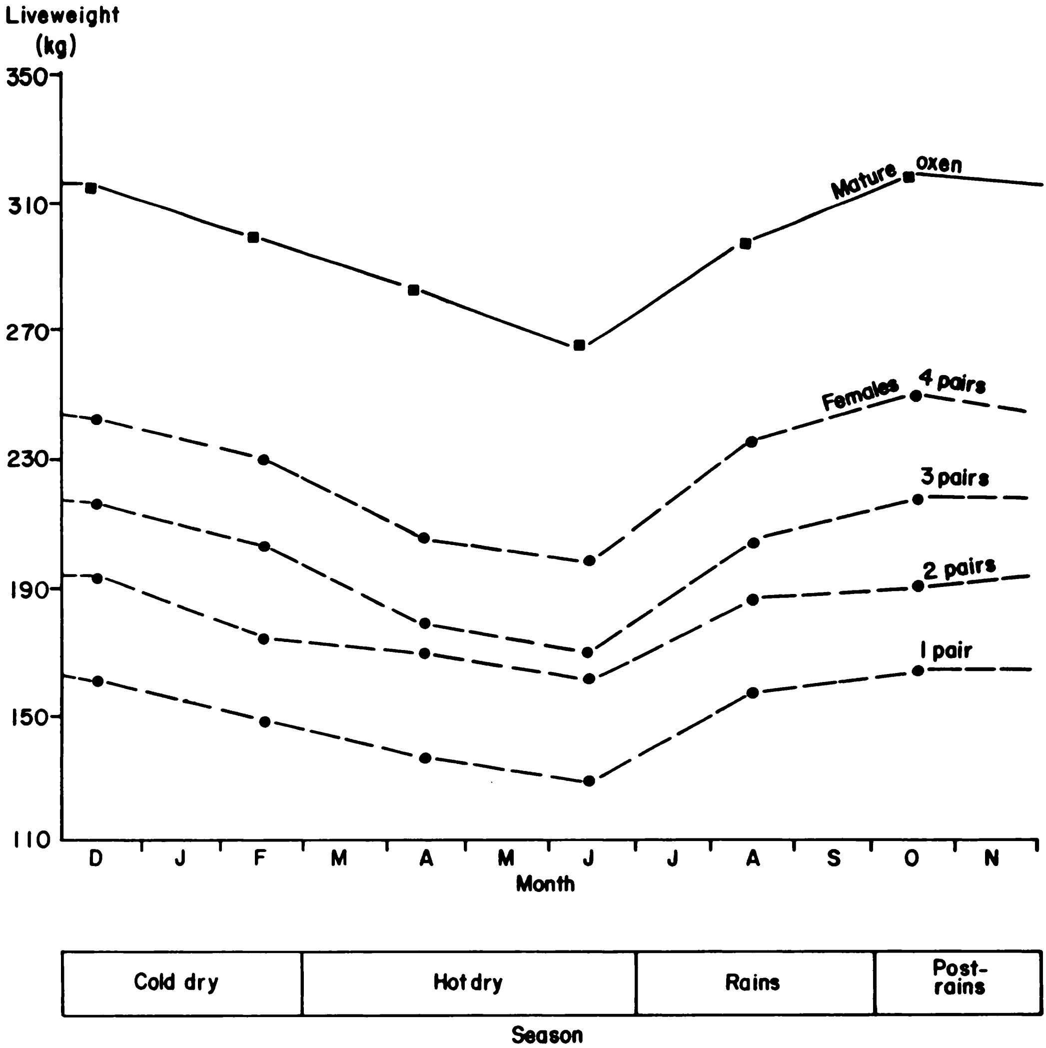


Figure 36. *Long-term weight changes in oxen and breeding cows related to changes in rainfall.*

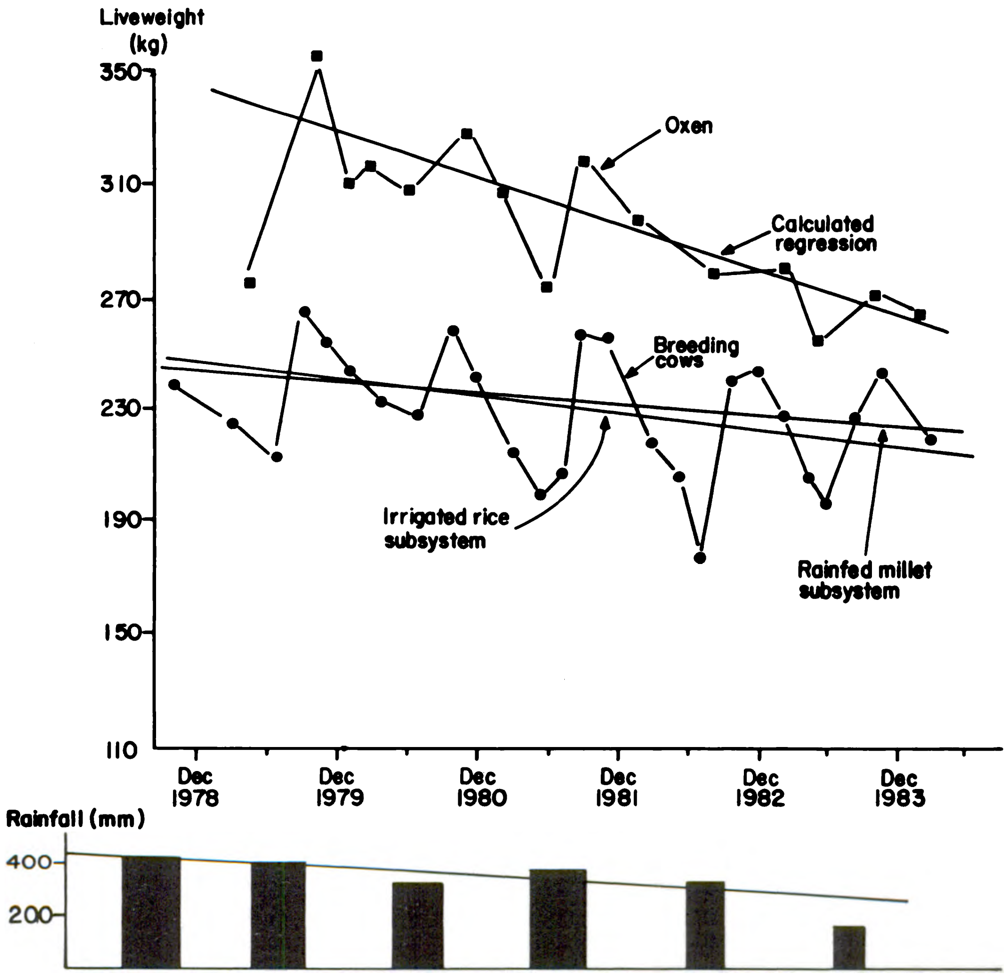


Table 28. *Regression analyses[a] of weight (kg) on time for different classes of cattle and of rainfall (mm) on time, 1977–1983.*

Subsystem and class		Number of observations	a	b	r	P
Rice						
Mature work oxen		835	−1.37	378.6	−0.3856	0.0000
Females	4 pairs incisors	1 364	−0.56	259.3	−0.2279	0.0000
	3 pairs incisors	341	−0.57	237.8	−0.2322	0.0000
	2 pairs incisors	272	−0.36	200.7	−0.1821	0.0013
	1 pair incisors	246	−0.51	183.3	−0.2265	0.0002
Millet						
Females	4 pairs incisors	1 070	−0.38	252.2	−0.1972	0.0000
	3 pairs incisors	229	0.48	175.5	0.1924	0.0017
	2 pairs incisors	193	−0.03	181.4	−0.0188	0.3978
	1 pair incisors	155	−0.40	175.8	−0.2194	0.0030
Rainfall		7	−33.40	452.1	−0.7871	0.0450

[a] $y = ax + b$, intercept at January 1977.

9. MORTALITY AND OFFTAKE

ABORTIONS

A total of 15 (3.32%) of all the 452 births recorded were abortions.

MORTALITY TO 4 YEARS OF AGE

Details of deaths to 4 years of age are given in Table 29. The calculated overall figure was 31.6% of all animals born (excluding abortions – if these are included, the figure would be 34.9%), although a true figure would be slightly higher than this as a number of animals had not reached 4 years. Deaths to weaning at about 7 months of age were about 9% (Figure 37), with the major risk of dying during the first month of life. There was a low death rate between weaning and 1 year of age. A major crisis period for young animals was during their second year of life, this being followed again by a low death rate between 2 and 3 years of age and an almost negligible risk of dying in the fourth year.

As can be seen from Table 29, the system, the season of birth and the year of birth had significant effects on the levels of mortality.

MORTALITY IN ADULT CATTLE

Cattle over 4 years old (those with four pairs of permanent incisors if actual age was not known) were considered to be adult. The number of adult cattle years was calculated for the whole study period as 1877.5. A total of 94 adult cattle died (including eight lost and not recovered). The death rate was calculated as 94/1877.5 x 100, this being equal to 5.01%.

OFFTAKE

Offtake was calculated as sales plus slaughter (for social purposes or *in extremis*) plus animals gifted-out permanently. A few slaughters and sales (especially the latter) took place before animals were mature. Calculated on the same basis as adult mortality, total offtake was 8.36% composed of 0.53% slaughtered, 6.98% sold and 0.85% gifted animals.

DISCUSSION

Abortion – at least in late pregnancy when it can be more easily detected – has been a minor problem since 1978. The main periods at which death occurred were the first months of life and the second year of age. It is probable that some young animals did not receive sufficient attention in early life to enable them to survive. The second-year death rate most probably resulted from an accumulation of general stress and disease factors.

No specific diseases were identified as major causes of death during this phase of the study, although liver fluke has since been identified as a contributing factor in the general debility (Traoré, 1984). A constantly low – and decreasing in the long term – level of nutrition plays a major overall part in animal losses.

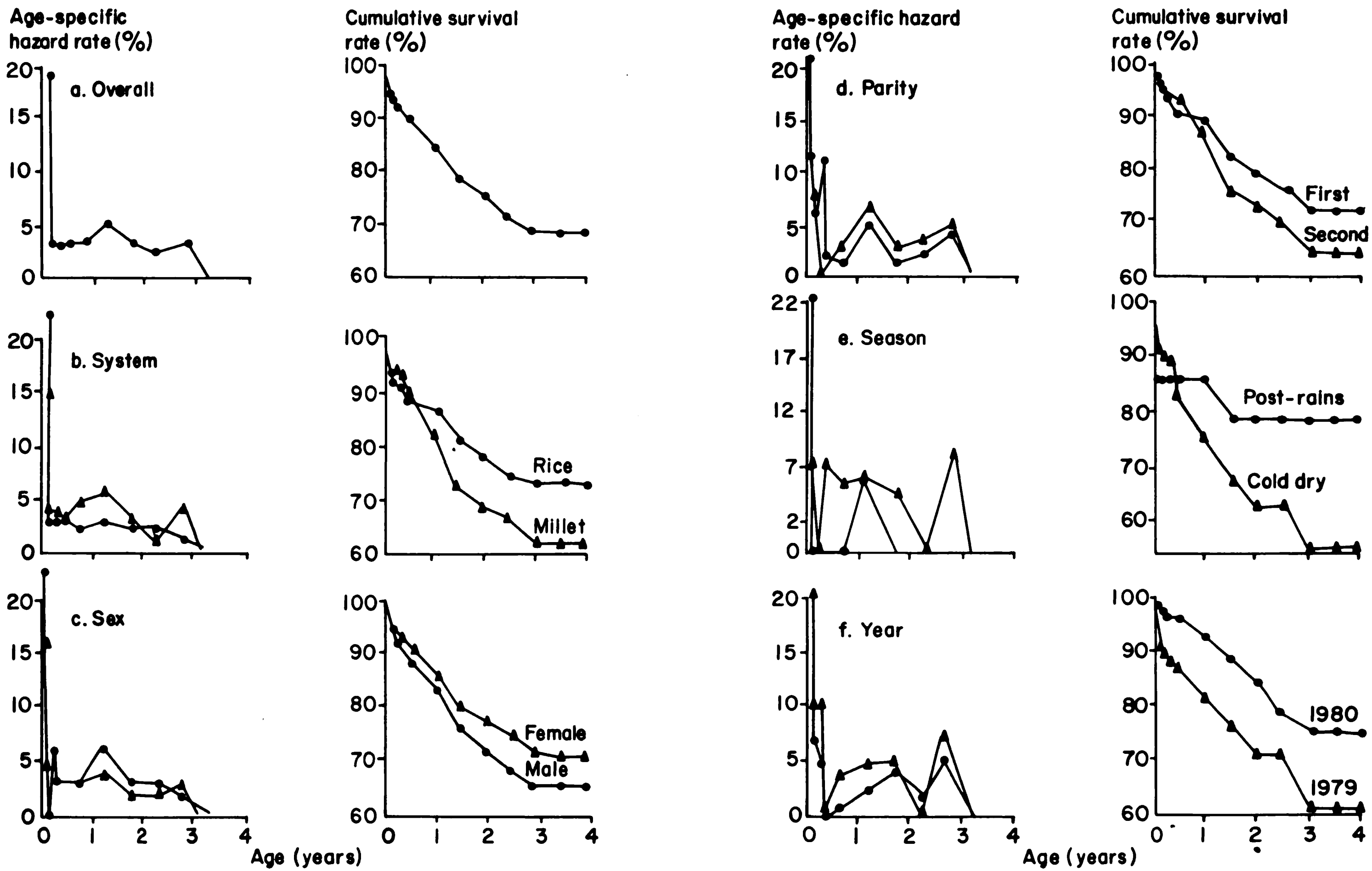
Overall, the abortion rate recorded in this study was considerably lower than that found on the Station du Sahel from 1966 to 1976, and the total mortality rate was not much higher than the 26% to 3 years of age recorded there (ILCA/IER, 1978).

Table 29. *Observed mortality rates[a] for agropastoral cattle to 4 years of age, presented by different variables.*

System	%	Sex	%	Parity	%	Season of birth	%	Year of birth	%
Millet	37.3	Female	29.2	1	27.7	Cold dry	41.7	1978	28.6
Rice	26.3	Male	34.3	2	36.5	Hot dry	27.4	1979	39.5
				3	31.2	Rains	46.0	1980	27.4
				4	28.6	Post-rains	21.4	1981	31.7
				'9'	32.7			1982	35.7
								1983	3.0
Mantel-Cox Test									
Statistic	4.82		1.55		1.77		9.67		15.23
d.f.	1		1		4		1		5
Significance	0.0281		0.2831		0.7784		0.0216		0.0094

[a] $\bar{x}$ = 31.6%.

Figure 37. *Age-specific hazard and cumulative survival rates for agropastoral cattle in central Mali.*



10. PRODUCTIVITY

MEAT PRODUCTION: A CASE STUDY AT NIONO SLAUGHTERHOUSE

Numbers and seasonality of animals slaughtered

In the year from March 1979 to February 1980, a total of 1075 cattle, 643 sheep and 5794 goats were slaughtered at Niono slaughterhouse. Chi-square tests showed highly significant differences ($P<0.001$) in the monthly numbers of animals slaughtered. There were significant increases ($P<0.01$) in the numbers of cattle (1210) and sheep (756) slaughtered in the following year (March 1980–February 1981) but not ($P>0.05$) in the numbers of goats (5858). A very small number of camels – 20 to 30 head per year – were also slaughtered.

Sex and age structure

For all three species, females were the dominant sex slaughtered although to a lesser extent in the case of goats. This is well illustrated by Figure 38 which shows that 68% of cattle, 76% of sheep and 54% of goats slaughtered at Niono were females. The greater numbers of females slaughtered are due to a considerable extent to the much greater demand for male animals for export (in the case of cattle and sheep), and also to the demand for work oxen.

For all species, females were generally in the older age ranges having outlived their useful reproductive life. Broken-mouthed animals totalled some 25% of all females in the oldest age group (both full and broken-mouthed females are shown with four pairs of permanent incisors in Figure 38).

Carcass weights

The overall weighted mean carcass weight for cattle was 109.4 kg. This is 32.6% lower than the official figure of 145 kg used in national statistics.

Contribution of cattle to meat supply

As can be seen from Figure 39, cattle provided most of the marketed meat in Niono town, this being equivalent to about 60% of the total supply. At certain times of the year, however, they provided less meat than goats, indicating some complementarity of these two species. Beef available to the urban population of Niono through commercial channels was 7.5 kg per person in 1979/1980 and 7.8 kg in 1980/1981, excluding edible offal. However, cattle do not provide proportionately as much offal as do small ruminants due to the significantly smaller proportion of lungs ($X^2 = 9.13$, d.f. = 1, $P<0.01$) and liver ($X^2 = 10.40$, d.f. = 1, $P<0.01$) condemned for diseased states among small ruminants.

MILK PRODUCTION

Few data were obtained on this characteristic. Average milk offtake for human consumption was estimated to be 1.088 litres per day with a range of 0.502 to 2.490 litres for individual animals at different stages of lactation. Lactation length averaged 297 ± 81 days in the range 200 to 506 days. Total lactation offtake for human consumption was estimated at 323 litres.

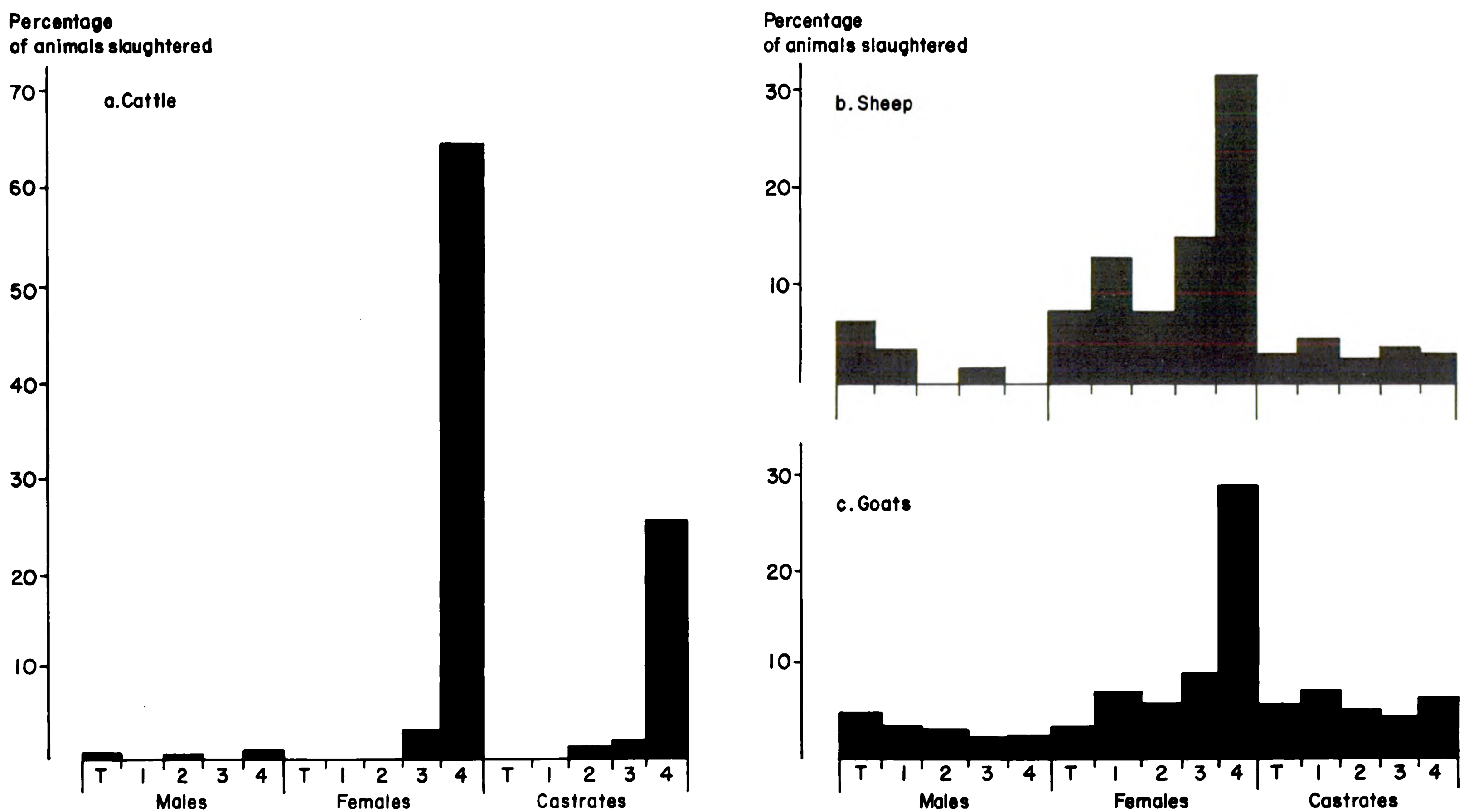
PRODUCTIVITY INDICES

The characters of calf weight at 12 months of age, reproductive performance (expressed as the parturition interval) and calf survival (the death of a calf resulting in a zero index for that cow) have been used to construct productivity indices for individual cows.

The three indices used were calculated as:

$$\text{Index I} \quad \text{Weight of calf produced per cow per year} = \frac{\text{Calf weight at 12 months} \times 365}{\text{Subsequent parturition interval}}$$

Figure 38. *Sex and age[a] composition of animals slaughtered at Niono slaughterhouse.*



[a]T = Temporary teeth.
1, 2, 3 and 4 = pairs of permanent incisors.

Index II Weight of calf produced per kg liveweight of cow per year $= \dfrac{\text{Index I}}{\text{Cow postpartum weight}}$

Index III Weight of calf produced per kg metabolic weight of cow per year $= \dfrac{\text{Index I}}{\text{Cow postpartum weight}^{0.73}}$

In total, 247 indices were calculated and were used in least-squares analysis to test for the effects of different variables on the indices. Year effects were not tested because of the long parturition intervals in relation to the total period of the study. The results of the analysis of variance for the three productivity indices are shown in Table 30.

The least-squares means of the three productivity indices are given in Table 31. Only parity had any significant effect on productivity, first calvers being less productive than all other classes of cows except third calvers. No other variable exerted a significant effect, this probably being due to the overall poor level of performance.

Herd productivity would be less by some 5% than that given in Table 31 due to deaths of breeding females.

Figure 39. *Species contribution to meat supplied from Niono slaughterhouse.*

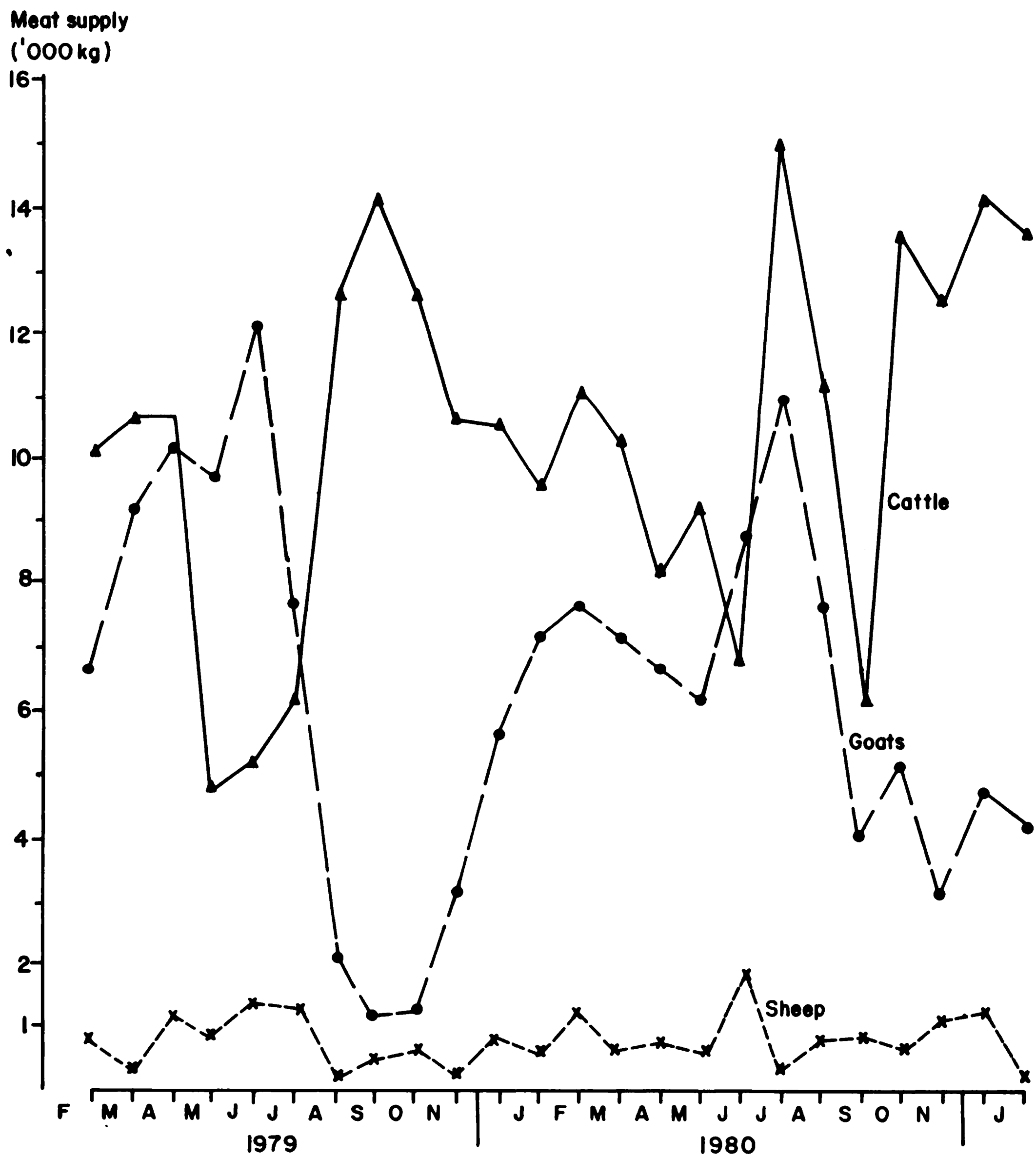


Table 30. *Analysis of variance of cattle productivity indices.*

Source of variation	d.f.	Index I	Index II ($x 10^4$)	Index III ($x 10^4$)
System	1	17.0	9.2	12.6
Season	3	391.0	120.5	1 819.5
Parity	3	2 751.9***	246.8	5 530.4*
Sex	1	99.6	103.5	1 677.8
Herd/millet	3	559.1	41.1	827.8
Herd/rice	4	457.9	108.2	1 935.1
Error	132	457.8	108.2	1 935.1

***P<0.001; *P<0.05.

Table 31. *Least-squares means of cattle productivity indices.*

Variable	n	Index I (kg) $\bar{x}$	Index II (g) $\bar{x}$	Index III (kg) $\bar{x}$
Observed mean	247	34.40	164	0.698
Overall LS mean	247	36.20	163	0.704
System				
Millet	106	36.61	161	0.702
Rice	141	35.96	166	0.707
Season				
Cold dry	39	37.57	168	0.722
Hot dry	167	36.44	176	0.747
Rains	30	30.09	134	0.587
Post-rains	11	41.04	176	0.762
Parity				
1	74	28.16a	140	0.586a
2	50	52.09b	181	0.782b
3	32	33.88ab	155	0.677ab
4+	91	41.02b	178	0.722b
Sex				
Female	136	35.62	157	0.677
Male	111	36.95	170	0.732
Herd/millet				
5	11	40.45	168	0.739
7	12	43.04	181	0.787
8	50	32.80	148	0.636
15	33	30.17	146	0.644
Herd/rice				
53	39	34.45	171	0.730
60	33	33.20	147	0.619
64	39	33.67	149	0.643
67	16	40.71	187	0.798
69	14	37.77	176	0.745

Within variable groups, means followed by different letters differ significantly (P<0.05). Variable groups without any letters did not show a significant difference in the analysis of variance.

PART THREE

SMALL RUMINANT PRODUCTIVITY

11. REPRODUCTIVE PERFORMANCE

Reproductive performance has been analysed under three main headings: early reproductive performance; overall reproductive performance including litter size, parturition intervals and annual reproductive rate; and effects of a number of climatic variables on reproduction. Most data result from the long-term study although some data from specific short-term studies have been included where considered appropriate.

AGE AND WEIGHT AT EARLY PARTURITIONS

Histograms of the observed distributions of weight at first conception are given in Figure 40 for both goats and sheep. The mean weights ($\bar{x} \pm$ s.d.) for goats were 16.6 ± 3.46 kg in the range 6.8 – 29.5 kg and for sheep 22.8 ± 4.29 kg in the range 12.8 – 45.6 kg.

At first parturition the age of goats averaged 485 ± 128.87 days in the range 275 – 1104 days while for sheep age at first parturition was 480.2 ± 115.27 days. At second parturition the figures for goats and sheep respectively were 760.7 ± 144.46 days in the range 471 – 1300 days and 756.3 ± 128.45 days in the range 546 – 1221 days. The frequencies of the observed distributions for these data are shown in Figure 41.

Figure 40. *Distribution of weights at first conception for goats and sheep in central Mali.*

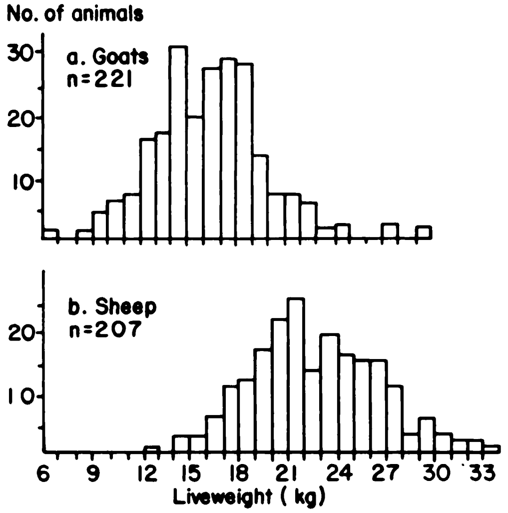
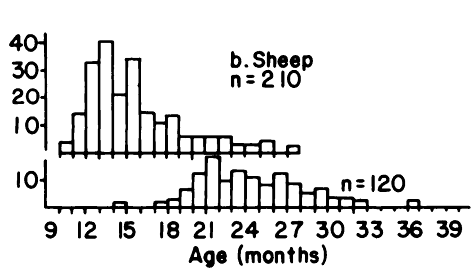


Figure 41. *Ages at first and second parturitions for goats and sheep in central Mali.*



The mean-squares values for the three traits are laid out in Table 32 while the least-squares means are given in Table 33. There was a significant effect of system on weight at first conception, with animals from the rice area being significantly heavier ($P<0.05$ for goats and $P<0.001$ for sheep) than those from the millet subsystem. Month of birth and maternal parity also had a highly significant effect on sheep weights. Sheep weighed significantly ($P<0.001$) more than goats at first conception. System was the only variable to have a significant effect on age at first and second partu-

Table 32. *Analysis of variance of weight at first conception and ages at first and second parturitions for goats and sheep in central Mali.*

Source of variation	Weight at first conception				Age at first parturition				Age at second parturition			
	Goats		Sheep		Goats		Sheep		Goats		Sheep	
	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS
System	1	429*	1	17 978***	1	11 399	1	145 185***	1	8 516	1	101 710**
Month of birth	11	84	11	4 766***	11	16 998	11	15 121	11	20 496	11	9 796
Type of birth	1	156	1	52	1	37 552	1	478	1	2 440	1	34 752
Parity	7	35	7	3 976**	7	18 006	7	12 901	7	8 640	7	14 160
Flock/millet	12	357***	12	5 049***	12	39 217**	12	30 442***	12	64 618***	12	18 934
Flock/rice	4	130	5	320	4	90 408***	5	11 041	4	35 296	5	37 053*
Error	264	110	239	1 324	270	14 649	242	10 269	129	16 135	133	13 201

***$P<0.001$; **$P<0.01$; *$P<0.05$.

Table 33. *Least-squares means for weight at first conception and ages at first and second parturitions for goats and sheep in central Mali.*

Variable	Weight (kg) at first conception				Age (days) at first parturition				Age (days) at second parturition			
	Goats		Sheep		Goats		Sheep		Goats		Sheep	
	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$
Raw mean	301	16.6	277	22.8	307	485.5	280	480.2	166	760.7	171	756.3
Overall LS mean	301	17.1	277	22.8	307	496.9	280	463.9	166	762.8	171	721.8
System												
Millet	239	16.4a	186	21.6a	244	508.2	189	497.0a	136	779.8	121	760.0a
Rice	62	17.8b	91	24.0b	63	485.6	91	430.7b	30	745.9	50	683.6b
Month of birth												
January	13	17.3	30	21.2ad	14	467.8	30	424.9	10	785.6	12	676.3
February	17	15.4	17	23.0ac	17	363.1	17	480.8	14	674.9	9	699.5
March	33	17.5	26	22.2aef	34	490.2	26	472.6	22	765.5	21	731.7
April	24	18.1	16	21.3agh	24	554.8	16	481.5	14	793.1	11	764.7
May	15	17.0	15	23.0aij	16	468.1	16	479.3	5	680.1	11	711.7
June	12	17.3	16	24.1bcegikln	12	543.7	16	499.4	5	778.5	11	763.8
July	10	17.6	19	22.9akm	10	529.3	19	457.4	4	872.1	9	750.3
August	8	16.7	15	26.6n	8	479.4	15	509.0	2	834.5	9	755.1
September	45	17.3	35	23.9bcjmo	45	495.3	35	460.1	29	770.5	22	705.9
October	37	17.3	28	22.6alo	40	494.0	28	426.2	23	709.4	17	716.8
November	53	16.6	32	20.7dfhp	53	510.1	32	444.2	15	762.5	20	684.8
December	34	16.7	28	21.5ap	34	466.8	30	431.0	13	727.3	19	700.9
Type of birth												
Single	193	17.4	260	22.9	198	483.5	262	460.7	105	768.0	156	753.9
Twin/triplet	108	16.8	17	22.7	109	510.3	18	467.0	61	757.7	15	689.6
Parity												
'0'	124	16.8	58	25.1a	129	492.9	60	497.2	79	791.3	39	749.4
1	46	16.8	58	23.0bc	46	517.7	58	486.7	26	760.3	32	757.9
2	43	16.6	62	23.8acde	43	480.0	62	479.5	25	757.6	35	707.3
3	33	16.9	46	22.1bf	33	523.6	47	444.6	15	791.1	33	710.6
4	23	17.8	24	22.4bdg	23	501.4	24	464.6	11	782.2	16	719.0
5	15	16.7	13	22.7acfgh	16	489.3	13	469.3	8	754.2	7	772.4
6	10	17.2	8	21.9beh	10	414.5	8	430.9	1	592.4	5	645.7
7–10	7	17.7	8	21.1beh	7	555.8	8	438.0	1	873.7	4	712.1

Note: Parity '0' = all unknown parities assumed to be ≥4.

Within variable groups, means followed by different letters differ significantly (P<0.05). Variable groups without any letters did not show a significant difference in the analysis of variance.

ritions, with the effect being confined to sheep. Although in goats the system effect was not significant, those reared in the rice areas also had their first and second parturitions earlier. Flock within system had significant effects on all the traits, with the effects being much more marked in the naturally less well endowed millet area.

There was no significant correlation between age at first parturition and the interval to the second parturition either for goats ($r = 0.20$, $P>0.05$) or for sheep ($r = 0.03$, $P>0.05$).

LITTER SIZE, PARTURITION INTERVAL AND ANNUAL REPRODUCTIVE RATE

Annual reproductive rate (ARR) was calculated as a function of litter size and parturition interval according to the formula: litter size x 365/subsequent parturition interval. Calculations for parturition interval and ARR were limited to animals having given a previous birth in 1983 in order that short intervals would not bias the results.

During the study period there was a total of 3605 parturitions giving rise to 4049 young. The distribution of births and young is shown in Table 34. Mean litter size ($\bar{x} \pm$ s.d.) for goats was 1.19 ± 0.41 and for sheep 1.04 ± 0.21. Litter size increased from 1.04 for primiparous goats to a maximum of 1.39. In sheep, litter size varied from 1.01 for primiparous females to 1.13 in older animals.

The observed distribution of parturition intervals is shown in Figure 42. The mean for goats was 291 ± 105.2 days and for sheep 261 ± 76.3 days. The longest interval for goats (298 ± 99.2 days) occurred between the first and second parities and the shortest (208 ± 45.4 days) after the ninth parity. For sheep, the longest interval (208 ± 63.6 days) was again after the first parity, with a decrease in the length of the interval in subsequent parities. Overall annual reproductive rates, calculated from the two previous parameters, were 1.49 for goats and 1.45 for sheep.

These data from the long-term study can be compared with those from a rapid survey carried out in early 1978 which attempted to establish the distribution of types of birth and litter size by age class. The main results from this small study are shown in Table 35.

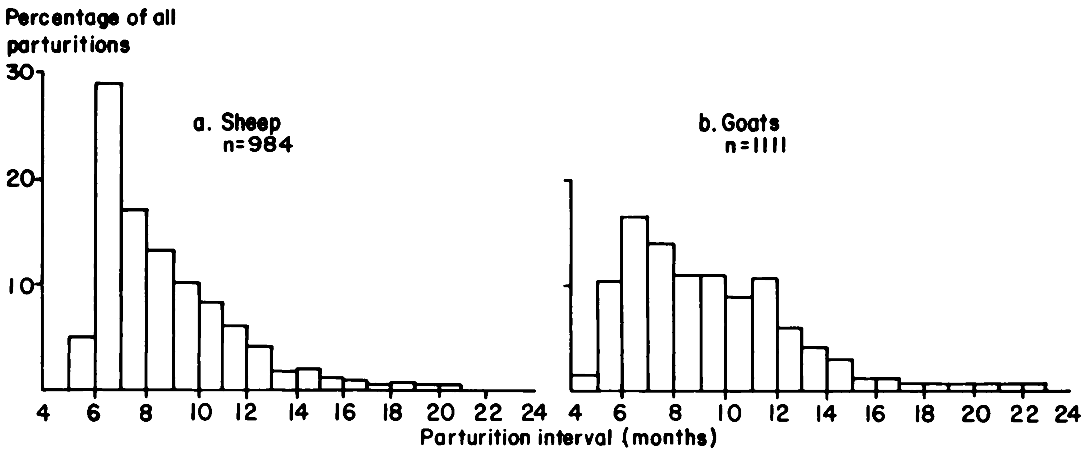
Mature animals with an unknown breeding history were not included in the least-squares analyses. Parity in this set of analyses refers to the order of births in the reproductive career of the animal whose records are being analysed and not, as in the section on early reproductive performance, to the parity of its dam. Parities greater than 4 were grouped and treated as fourth parity and triplet and twin parturitions were grouped as multiple births. A separate analysis was carried out for each parameter for each species. The models considered the random effect of dam within system and within flock and the fixed effects of system, flock, season and year of parturition, type of birth, sex of offspring and parity. During preliminary analyses, system (rainfed millet and irrigated rice) was seen to have significant effects on some of the traits being studied. Because of the limitations of the models, the main analyses were therefore carried out by systems with dams within flocks as the random variable. Orthogonal polynomials were fitted to some of the main variables in an attempt to further understand some of the influences acting on them.

Levels of significance for the different sources of variation acting on the three measured traits are shown in Table 36. System influenced significantly all three traits in sheep but none at all in goats. All further analyses resulting from this analysis of variance were however carried out by system with flock introduced as a fixed effect. The practical results of the effects of system on sheep

Table 34. *Numbers of parturitions and percentages of young by parturition type for sheep and goats in central Mali.*

Type of birth	Sheep		Goats	
	No.	%	No.	%
Total births	1 650	100.0	1 955	100.0
Total young	1 722	100.0	2 327	100.0
Single births	1 579	95.7	1 593	81.5
Young born as singles	1 579	91.7	1 593	68.5
Twin births	70	4.2	350	17.9
Young born as twins	140	8.1	700	30.1
Triplet births	1	0.1	12	0.6
Young born as triplets	3	0.2	36	1.5

Figure 42. *Frequency distribution of parturition intervals for sheep and goats in central Mali.*



were that those in the rice subsystem had a better total reproductive performance than those in the millet subsystem. This was probably due to the better year-round feed conditions in the former subsystem, a hypothesis supported by the lack of significance in the seasonal effect on all three traits for sheep.

The least-squares means for the three traits are shown in Table 37 for sheep and in Table 38 for goats. Table 39 provides data on the best-fit polynomials for variables where significance occurred in the main analyses, and Figure 43 shows in graphic form the calculated orthogonal fits. Other than the effects of the flock factor, and with the exception of the effects of year and parity on litter size in goats in the rice subsystem, all significant effects are confined to one or the other species in the millet subsystem.

EFFECTS OF CLIMATE ON THE PERIOD OF BIRTH AND ON LITTER SIZE

For these analyses the numbers of births and the mean number of young per birth were calculated for each 10-day period from 1978 to 1983. Simple correlations and multiple linear regressions were then calculated between these data and six climatic variables for each of the 15th to 20th 10-day periods prior to those being analysed for numbers of parturitions and litter size. BMDP programmes (Dixon and Brown, 1983) were used for the statistical analyses.

The distribution of 1702 parturitions for goats and 1500 for sheep by month is shown in Figure 44 which also shows the mean litter size by month. There were highly significant differences among months for the numbers of parturitions in goats (X^2 = 553.8, d.f. = 11, P<0.001) and for those in sheep (X^2 = 108.0, d.f. = 11, P<0.001). The minimum number of parturitions (54) in goats occurred in August and the maximum (323) in November. In sheep, the minimum number (88) was in May, the maximum (174) being in September.

Litter size in goats varied from a maximum of 1.31 kids in March to a minimum of 1.14 in both August and October. In sheep, maximum litter size of 1.14 lambs was achieved in April with a minimum of 1.01 in September. An analysis of variance showed significant differences among months for both goats (F = 5.55, d.f. = 11,1657, P<0.001) and sheep (F = 3.90, d.f. = 11,1444, P<0.001).

The maximum number of conceptions in both goats and sheep took place in May to July while the maximum number of ova appeared to be shed in October and November in goats and perhaps slightly later (in November and December) in sheep. The smallest number of conceptions in goats took place in February and March, while in sheep there was a fairly clearly defined period of poor conception rates extending from October through March. Monitoring actual oestrus activity in sheep in the Egyptian subtropics, Aboul-Naga et al (1985) found it to be irregular throughout the year but with a minimum in April. Monitored by hormone levels in Niger, in climatic conditions similar to those at Niono, minimum oestrus activity and longest cycles were found from January to April (Yenikoye et al, 1982). In the latter case, abnormally long cycles contributed to the low numbers of conceptions observed: there was, however, a rapid upsurge in oestrus activity from May onwards.

Correlations between goat parturitions and climatic variables were positive and highly significant for maximum temperature (r = 0.30 to

Table 35. *Reproductive performance of agropastoral goats and sheep, based on owners' recall data.*

	Sheep						Goats					
	4 pairs	3 pairs	2 pairs	1 pair	Temporary	Overall	4 pairs	3 pairs	2 pairs	1 pair	Temporary	Overall
Number in sample	37	21	22	42	16	138	180	77	61	111	15	444
Type of birth												
Single	124	52	43	41	7	267	457	139	81	77	5	759
Twin	9	2	2	1		14	203	11	4	1		219
Triplet	1					1	8					8
Total parturitions	134	54	45	42	7	282	668	150	85	78	5	986
Total young born	145	56	47	43	7	298	887	161	89	79	5	1 221
Average litter size	1.08	1.04	1.04	1.02	1.00	1.06	1.33	1.07	1.05	1.01	1.00	1.24

Table 36. *Analysis of variance of litter size, parturition interval and annual reproductive rate for sheep and goats in central Mali.*

Trait/species	Source of variation							
	System	Flock	Dam/Flock	Season	Year	Parity	Sex of young	Type of birth
Litter size								
All sheep	**	–	n.s.	**	n.s.	n.s.	–	–
MS[a] sheep	–	***	n.s.	**	n.s.	n.s.	–	–
RS[a] sheep	–	n.s.	n.s.	n.s.	n.s.	n.s.	–	–
All goats	n.s.	–	n.s.	**	n.s.	***	–	–
MS goats	–	**	n.s.	***	n.s.	***	–	–
RS goats	–	***	n.s.	n.s.	*	*	–	–
Parturition interval								
All sheep	***	–	***	**	n.s.	*	*	n.s.
MS sheep	–	***	*	***	**	n.s.	*	n.s.
RS sheep	–	**	*	n.s.	n.s.	n.s.	n.s.	n.s.
All goats	n.s.	–	**	*	**	n.s.	n.s.	n.s.
MS goats	–	***	**	n.s.	*	n.s.	n.s.	n.s.
RS goats	–	n.s.	**	n.s.	n.s.	n.s.	n.s.	n.s.
Annual reproductive rate								
All sheep	***	–	**	**	n.s.	n.s.	n.s.	–
MS sheep	–	***	n.s.	**	n.s.	n.s.	n.s.	–
RS sheep	–	*	*	n.s.	n.s.	n.s.	n.s.	–
All goats	n.s.	–	n.s.	n.s.	*	*	n.s.	–
MS goats	–	***	n.s.	n.s.	*	*	n.s.	–
RS goats	–	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	–

***$P<0.001$; **$P<0.01$; *$P<0.05$; n.s. = not significant.

[a] MS = millet subsystem; RS = rice subsystem.

0.47), minimum temperature (r = 0.25 to 0.42) and day length (r = 0.27 to 0.40) for all of the 10-day periods from the 15th to the 20th previously. A similar pattern was observed for sheep with correlations ranging from 0.29 to 0.39 for maximum temperature, from 0.17 to 0.37 for minimum temperature, and from 0.25 to 0.42 for day length. There were significant positive correlations also between the parturition interval and both maximum and minimum humidity at the 15th period for both goats and sheep and between parturition interval and rainfall at the 15th period for sheep, but no other periodic conditions were significant for these parameters and some were negative.

The litter size of goats showed significant correlations with maximum temperature (r = 0.14 to 0.19) at the 17th to 19th periods and with both maximum humidity (r = 0.16 to 0.22) and minimum humidity (r = 0.14 to 0.22) at the 17th to 20th periods previously. In sheep, litter size was significantly correlated only with maximum humidity (r = 0.16 to 0.26) and minimum humidity (r = 0.15 to 0.26) for all of the 15th to 20th periods in the case of the former and from the 17th period in the case of the latter.

When stepwise multiple regression was done, the final equations containing terms significant at the 5% level accounted for a low proportion of the variance. The maximum variance accounted for by parturitions in goats was 25.8% at the 17th period previously, with maximum temperature accounting for 19.9% of this and day length for the rest. For sheep, the maximum variance accounted for, at the 18th period, was 17.7% with maximum temperature contributing 14.6% and day length the rest.

The total amount of variance accounted for by litter size was much lower, being 6.7% at the 19th period with minimum humidity accounting for 3.7% and minimum temperature for 2.9%. In sheep, most variance (6.7% and 6.8% respectively) was accounted for by relative humidity at the 19th and 20th periods previously.

NUMBERS OF BIRTHS BY AGE CLASS

During the rapid study already referred to it was possible to obtain an indication of the numbers of births by each class of age of female. The main results are provided in Table 40. For sheep, ewes with milk teeth and one to four pairs of permanent incisors had given birth 0.43, 1.00, 2.05, 2.57 and 3.62 times respectively, the overall number of births per breeding female in the flock being 1.84. For goats, the numbers of births were 0.33, 0.70, 1.39, 1.95 and 3.71 for the individual age groups and 2.22 births for all does in the flock. For both species there was a rapid reduction in the number of females having given birth more than five times.

DISCUSSION

Early reproductive performance

The mean age at first kidding of 463 days is in good agreement with the few other existing data for goats of a similar type managed under traditional systems in the West African semi-arid zone. For example in Chad, it has been found that age at first parturition varies from 418 to 502 days depending on the region (Bertaudière, 1979; Dumas, 1980). In Niger, Gerbaldi (1978) found that Sahel-type goats first kid at 401 ± 24 days. In southern Niger, the Red Maradi goat had an age of 427 ± 13 days at first kidding (Haumesser, 1975).

The age at first lambing of 474 days also agrees well with other published reports. In Chad, mean age at first lambing varied from 395 to 502 days depending on the region (Gerbaldi, 1978; Haumesser and Gerbaldi, 1980).

Management practices to control breeding are generally designed to delay the age at first parturition. This applies whether the management is traditional, as in the case of the Maasai pastoral system (where an apron is used to cover the penis of the male and some flock stratification is evident) where the age at first kidding is 556 ± 119 days and at first lambing 549 ± 112 days (Wilson et al, 1984), or under station conditions, as in Senegal (where males are separated from the females when breeding is not desired and females are mated only on attaining a specified minimum weight) where age at first lambing is 572 ± 24 days (Fall et al, 1982).

The greater weight at first conception in the irrigated rice subsystem reflected the differences in food availability between the rice and millet subsystems, and the generally faster growth rates (from birth weights of 1.8 kg for goats and 2.6 kg for sheep in both subsystems) and heavier mature weights achieved in the rice subsystem (31.8 kg for goats and 35.9 kg for sheep), compared to the millet subsystem (28.1 and 32.1 kg respectively for goats and sheep). Earlier physical maturity in the rice subsystem at first conception also apparently results in slightly earlier physiological maturity, reflected in the 35-day younger age at first parturition.

The only other variable to affect significantly the age at first parturition is maternal parity, with

Table 37. *Least-squares means for litter size, parturition interval and annual reproductive rate of sheep in central Mali.*

Variable	Millet subsystem					Rice subsystem				
	Litter size		Parturition interval		Annual reproductive rate	Litter size		Parturition interval		Annual reproductive rate
	n	No. of young	n	Days	Young/year	n	No. of young	n	Days	Young/year
Overall	909	1.036	502	290	1.53	445	1.031	257	259	1.63
Flock[a]										
1	85	1.012	40	304	1.37	86	1.032	31	257	1.59
2	35	1.021	19	251	1.69	160	1.089	102	237	1.85
3	39	1.152	26	262	1.99	74	1.045	49	228	1.73
4	50	1.022	27	317	1.40	58	0.984	36	241	1.65
5	207	1.011	115	265	1.61	24	1.006	13	310	1.37
6	101	1.016	65	271	1.56	43	1.033	26	279	1.57
7	54	1.016	28	308	1.40	–	–	–	–	–
8	78	1.010	45	302	1.42	–	–	–	–	–
9	31	1.117	20	264	1.80	–	–	–	–	–
10	122	1.033	59	288	1.54	–	–	–	–	–
11	32	1.002	15	365	1.18	–	–	–	–	–
12	37	0.999	19	303	1.36	–	–	–	–	–
13	38	1.053	24	275	1.57	–	–	–	–	–
Average SE		0.0236		18.1	0.096		0.0316		19.6	0.115
Season										
Cold dry	271	1.053	147	297	1.46	101	1.039	45	262	1.62
Hot dry	206	1.074	117	285	1.63	143	1.054	90	256	1.74
Rains	217	1.004	117	267	1.62	103	0.991	60	257	1.62
Post-rains	215	1.018	121	312	1.40	98	1.042	62	260	1.52
Average SE		0.0144		13.0	0.054		0.0327		16.0	0.086
Year										
1978	90	1.019	–	–	–	11	0.932	–	–	–
1979	101	1.023	81	306	1.48	26	1.054	16	222	2.01
1980	159	1.020	110	298	1.44	70	1.062	44	275	1.55
1981	159	1.023	122	296	1.47	79	1.070	60	258	1.66
1982	144	1.042	105	300	1.50	105	1.022	82	264	1.56
1983	166	1.065	84	252	1.75	107	1.048	55	274	1.36
1984	90	1.057	–	–	–	47	1.032	–	–	–
Average SE		0.0263		15.3	0.078		0.0751		24.8	0.165
Parity										
1	271	1.034	141	292	1.51	145	1.012	84	271	1.47
2	212	1.055	115	287	1.59	105	0.992	60	257	1.57
3	155	1.026	89	277	1.59	80	1.038	46	248	1.69
≥4	271	1.028	157	306	1.42	115	1.078	67	257	1.78
Average SE		0.0177		14.2	0.067		0.0396		17.8	0.104
Sex										
Female	–	–	272	281	1.56	–	–	116	256	1.55
Male	–	–	230	300	1.49	–	–	141	261	1.70
Average SE				11.7	0.039				14.2	0.067
Type of birth										
Single	–	–	487	269	–	–	–	242	253	–
Multiple	–	–	15	312	–	–	–	15	264	–
Average SE				15.4		–	–		16.8	

[a] Flocks in the millet and rice subsystems carrying the same number are not necessarily under the same ownership.

Table 38. *Least-squares means for litter size, parturition interval and annual reproductive rate of goats in central Mali.*

Variable	Millet subsystem					Rice subsystem				
	Litter size		Parturition interval		Annual reproductive rate	Litter size		Parturition interval		Annual reproductive rate
	n	No. of young	n	Days	Young/ year	n	No. of young	n	Days	Young/ year
Overall	1104	1.154	597	298	1.53	310	1.177	166	297	1.63
Flock[a]										
1	71	1.182	29	272	1.58	38	1.323	21	286	1.75
2	174	1.236	102	267	1.79	39	1.275	21	279	1.82
3	173	1.160	106	255	1.84	16	1.253	7	251	1.93
4	42	1.310	20	270	1.83	50	1.062	28	295	1.49
5	39	1.106	21	328	1.39	147	1.084	82	295	1.52
6	23	1.245	13	297	1.68	20	1.066	7	377	1.29
7	22	1.043	11	325	1.28	–	–	–	–	–
8	41	1.160	15	293	1.73	–	–	–	–	–
9	311	1.182	171	302	1.44	–	–	–	–	–
10	32	1.049	17	280	1.52	–	–	–	–	–
11	30	1.095	16	343	1.24	–	–	–	–	–
12	60	1.050	35	334	1.31	–	–	–	–	–
13	39	1.152	19	313	1.27	–	–	–	–	–
14	47	1.178	22	293	1.52	–	–	–	–	–
Average SE		0.0534		21.7	0.132		0.0599		27.9	0.161
Season										
Cold dry	260	1.245	140	316	1.50	69	1.161	27	287	1.67
Hot dry	252	1.186	146	291	1.62	75	1.190	40	296	1.52
Rains	184	1.076	114	281	1.56	39	1.144	31	283	1.79
Post-rains	408	1.107	197	305	1.44	127	1.214	68	322	1.55
Average SE		0.0301		12.0	0.072		0.0543		21.9	0.134
Year										
1978	61	1.164	–	–	–	–	–	–	–	–
1979	99	1.184	70	364	1.40	–	–	–	–	–
1980	148	1.208	101	304	1.68	46	1.298	33	303	1.72
1981	211	1.184	153	283	1.69	66	1.126	48	301	1.49
1982	223	1.110	153	278	1.51	67	1.269	49	313	1.54
1983	196	1.081	120	261	1.38	68	1.188	36	272	1.77
1984	166	1.143	–	–	–	63	1.004	–	–	–
Average SE		0.0579		17.7	0.112		0.0888		24.5	0.158
Parity										
1	370	1.004	197	274	1.37	102	1.028	54	299	1.41
2	256	1.093	157	294	1.36	67	1.060	41	295	1.54
3	186	1.205	106	299	1.65	58	1.277	30	271	1.87
≥4	292	1.311	137	326	1.74	86	1.343	41	324	1.71
Average SE		0.0368		14.7	0.095		0.0664		24.8	0.161
Sex										
Female	–	–	304	295	1.55	–	–	81	303	1.60
Male	–	–	293	301	1.51	–	–	85	291	1.67
Average SE				9.9	0.052				18.6	0.095
Type of birth										
Single	–	–	545	304	–	–	–	152	283	–
Multiple	–	–	52	293	–	–	–	14	312	–
Average SE				11.5					21.5	

Note: [a] Flocks in the millet and rice subsystems carrying the same number are not necessarily under the same ownership.

offspring of young and old mothers maturing later than those from dams in the intermediate (3–5 years) age groups. The reasons for this are not clear as there is no obvious relationship with weight at first conception.

On the whole the effects of environmental factors on age at first parturition are small. This was also found to be the case in Senegal where neither year, nor month nor type of birth had any significant effect on age at first lambing (Fall et al, 1982). It would appear, therefore, that little is to be gained by attempting to control breeding seasons to optimise age at first parturition. Mortality of young born to primiparous females is almost always higher than that of those born to older females. Although delaying first parturition to an age when the female is nearer to its full physical development reduces the death rate to some extent, the slower growth rate of the young is reflected in the lower productivity of this class of dam when compared with that of older dams. There is no evidence from traditional systems that early first parturitions result in subsequent diminished reproductive capacity and it is therefore probably worthwhile selecting for an early first parturition, accepting the higher death rate and lower productivity resulting from this and anticipating an extra parturition and a longer total reproductive life. Such a strategy might also enable a greater proportion of breeding females in the middle age groups to be maintained in relation to primiparous and older females, thus leading to further improvements in total flock productivity.

Main reproductive traits

The effects of parity are those which might logically be expected. Litter size increased linearly with age in goats in both subsystems. The lack of significance in sheep is probably due to the overall low level of twinning. The quadratic form of the parturition interval of sheep in the millet subsystem can be explained by the adaptation of the ewes to the different partitioning of resources as they grow, reach maturity and then senesce. Overall, however, the effects of parity on parturition interval are slight in sheep in the millet subsystem and do not affect sheep in the rice subsystem. The parturition intervals for goats are not affected by parity in either subsystem. The significant effect of parity on annual reproductive rate is confined to goats in the millet subsystem, resulting from increased litter size with advancing age of the dam.

The effects of year are difficult to interpret. It is possible, however, that the maximum annual reproductive rate in goats in the millet subsystem during the middle period of the current study is related to the recovery of animals and food resources from the effects of the 1968–1973 Sahel drought, followed by a decline due to the effects of lowered rainfall during the early 1980s and increased pressure on feed resources as a result of a build-up of stock numbers. Why the same phenomenon is not significant in sheep in the same subsystem is not clear.

Although the effects of flock are significant for most variables, it has not yet been possible to isolate the specific mechanisms which cause the differences. In traditional systems in Africa, access to the basic resources of grazing and water is theoretically equal for all flocks. It is possible that individual management abilities play a role in acquiring better use of these resources by ensuring that animals have adequate time at grazing and are given sufficient water on a regular basis. Other practices such as keeping night-holding pens or picket areas free of manure, and simple veterinary interventions, may also influence flock reproductive performance.

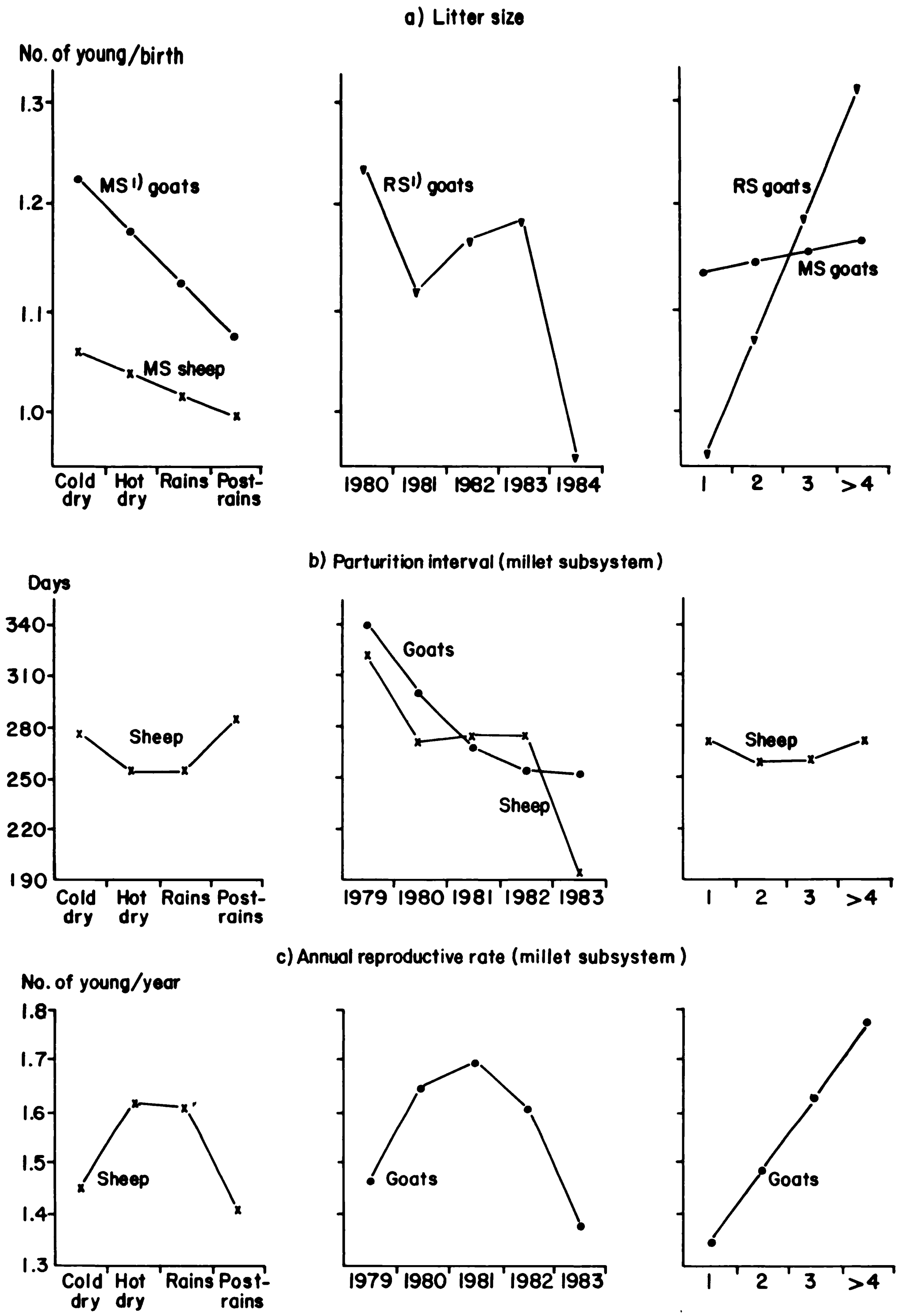
A comparison of these results with those available from similar studies indicates that traditionally managed goats and sheep in Mali have a reproductive performance close to the African average. Observed litter sizes for goats range from 1.23 in Kenya (Wilson et al, 1984) to 1.51 in Sudan (Wilson, 1976c) and for sheep from 1.05 in Kenya to 1.14 in Sudan (Wilson and Clarke, 1976b). In Sudan, goats have been recorded as having parturition intervals of 238 days and in Kenya of 306 days. Intervals for sheep range from 275 days in Sudan through 301 days in Niger (Haumesser and Gerbaldi, 1980) to 320 days in Kenya. In other studies where goats and sheep have been recorded together under the same conditions, goats have always shown clearly superior annual reproductive rates. In central Mali, more detailed research, particularly on management skills, is needed to explain the superiority of sheep over goats.

In the systems studied there appears to be little possibility of improving total reproductive performance by attempting to shorten the parturition interval. Evidence from other tropical areas indicates that the figures recorded in this study are optimal. Creole goats in Guadeloupe average 237 days and the Indian Malabar 300 days (Garcia and Gall, 1981). Blackbelly sheep in the West Indies average 248 days and Pelibuey-West Africa sheep in Central America have an average interval of 245 days (Fitzhugh and Bradford, 1983).

Table 39. *Data from the polynomial analyses of reproductive characteristics of goats and sheep in central Mali.*

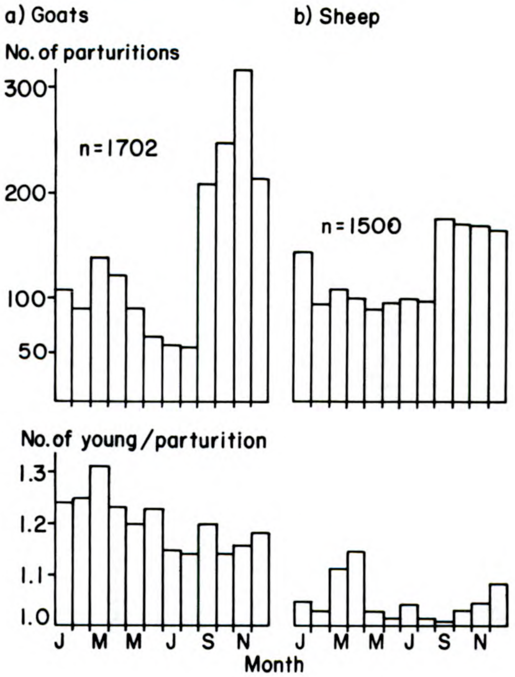
Species and trait	System	Variable	Orthogonal regression	Regression constants			
				a	b	c	d
Sheep							
Litter size	Millet	Season	Linear	1.028	−0.0191	–	–
Parturition interval	Millet	Season	Quadratic	249.0	2.458	14.65	–
		Year	Cubic	277.2	5.711	−4.93	−4.91
		Parity	Quadratic	256.8	3.077	8.38	
Annual reproductive rate	Millet	Season	Quadratic	1.64	−0.0169	−0.0978	–
Goats							
Litter size	Millet	Season	Linear	1.151	−0.0501	–	–
		Parity	Linear	1.151	0.0102	–	–
	Rice	Year	Cubic	1.172	0.0686	−0.0185	−0.0347
		Parity	Linear	1.135	0.1180		
Parturition interval	Millet	Year	Quadratic	270.6	−22.73	6.764	–
Annual reproductive rate	Millet	Year	Quadratic	1.700	−0.0231	−0.0682	–
		Parity	Linear	1.560	0.1392	–	–

Figure 43. *Best-fit estimates from the polynomial analyses of reproductive characteristics of sheep and goats in central Mali.*



1) MS = millet subsystem; RS = rice subsystem.

Figure 44. *Total number of parturitions per month and average number of young per parturition per month for goats and sheep in central Mali, 1978–1983.*



The potential for improving the annual reproductive rate by increasing litter size seems more feasible. Where selection has been practised, the number of kids per birth for Creole goats in Guadeloupe was 2.33, for the Damascus in Israel 1.76 and for the Beetal and Jamnapari in India 1.70 and 1.45 respectively (Garcia and Gall, 1981). Sheep litter sizes of 1.84 in the Barbados Blackbelly and 1.24 in the Pelibuey in the Caribbean have been recorded (Fitzhugh and Bradford, 1983). The possibilities of increasing litter size by crossing with the more prolific African types from similar environmental areas might also be considered.

Manipulating flock structure so that as many of the more productive females of older parity as possible are maintained, could also improve reproductive performance. Encouraging first parturitions at as early an age as feasible and selecting breeding stock on the basis of performance at first parturition (Ozakuma et al, 1982) would also boost the overall annual reproductive rate.

Climatic effects on reproduction

The positive correlation of the number of parturitions with day length found in this study is contrary to that found in seasonally breeding sheep in temperate latitudes and is also contrary to the postulate of Hafez (1951; 1952) that in the tropics, the breeding season of sheep is not affected by light i.e. day length. The pattern of births in this study is, however, similar to that recorded in Chad where 60 to 80% of births occurred from November to February (Dumas, 1980). The principal climatic source of variance is ambient temperature, this phenomenon also having been noted previously (Lees, 1971). The combined, interacting effects of temperature and day length on oestrus activity of sheep have also been noted in Niger (Yenikoye et al, 1982). No previous studies appear to have attempted to separate the effects of a simple conception from those of litter size.

The lack of significant correlations with rainfall is rather surprising. In cattle in this area, parturition is very highly correlated ($r = 0.56$, d.f. = 70, $P<0.001$) with rainfall 9 months previously (Section 7). As rainfall is almost uniquely responsible for primary production – except for the appearance of some browse – and as almost no supplementary feeding is practised in the systems studied, it does not appear that nutritional state is the proximal factor in the conception rate although it probably has more influence on the ovulation rate. The similar patterns of conception and of distribution of litter size in both goats and sheep are also puzzling in view of their different dietary habits.

More detailed experimental studies under controlled environmental conditions are required to explain fully the factors affecting fecundity and prolificacy in tropical goats and sheep.

Table 40. *Number of parturitions per breeding female by age class.*

Age by dentition class	Number of parturitions																		
	Sheep								Goats										
	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7	8	9	10
Milk teeth	9	7							10	5									
Permanent incisor pairs																			
1	8	29	2	3					42	62	5	2							
2		10	4	5	3				4	35	19	3							
3	1	3	6	6	4	1			2	22	39	12	2	1					
4			9	8	13	4	2	1	2	5	33	52	40	24	15	4	1	2	2
All sheep	18	49	21	22	20	5	2	1	60	129	95	69	42	25	15	4	1	2	2

12. GROWTH AND WEIGHT

BIRTHWEIGHT

The observed birthweight ($\bar{x}$ ± s.d.) of 581 goats born in the years 1978 to 1984 was 2.2 ± 0.64 kg. The mean birthweight for 613 sheep during the same period was 2.9 ± 0.88 kg.

The analysis of variance of this trait for goats is shown in Table 41: sex, parity, type of birth and year of birth of the kid exerted significant effects on its birthweight. The least-squares means for kid birthweights are given in Table 42. This shows that, as might be expected, males were heavier than females at birth, young of older females weighed more than those from younger dams, and twins (and triplets) were lighter than kids born as singles. Although the year of birth had a significant effect on birthweight, the observed variation can not be clearly related to the rainfall pattern over the study period.

The analysis of variance for birthweight in sheep (Table 43) shows that basically the same sources of variation acted on this trait as in goats although in addition there were highly significant differences due to system. The least-squares means for lamb birthweights are given in Table 44. Lambs born in the irrigated rice subsystem were heavier than those from the rainfed millet subsystem, their dams presumably benefitting from the better nutritional conditions in that zone. The other sources of variation exerted effects similar to those for goats.

GROWTH TO MATURITY

Generalised growth curves for goats and sheep from birth to maturity are given in Figure 45. Analyses of variance and estimated least-squares means for weights at various ages are shown in Tables 41 and 42 for goats and in Tables 43 and 44 for sheep. The observed sample means in Figure 45 differ from the least-squares means in Tables 42 and 44 as the data in the tables are adjusted for the unequal subclass numbers.

In goats, the system under which they were reared exerted a relatively minor effect (except at 150 and 240 days of age) until 1 year of age. The effects of parity were significant only up to 240 days and the effects of birth type, with the exception of some anomalous results around 2 years, were also quickly lost. Season of birth exerted a significant effect on weight only at 10 and 30 days. Sex had a consistently significant effect on weight as did year of birth. The effects of year of birth on growth to 3 years of age are shown in Figure 46. Kids born in 1981 exhibited a similar growth rate to those born in 1980, and kids born in all subsequent years again showed slower growth rates resulting in lighter weights-at-age when compared to kids born during 1978 and 1979.

In sheep, system had a highly significant effect on weight until mature weights were reached at about 3 years of age. The effects of the other sources of variation were similar to those observed for goats, with the exception of the effects of year of birth which were lost at about 1 year of age.

Average daily gains (calculated on the least-squares means) for goats from birth to 150, 365 and 1095 days were 58.0, 49.3 and 28.7 g/day respectively. In sheep, the average daily gains were 88.7, 66.9 and 33.3 g/day to the same ages. Asymptotic weights were achieved in sheep at about 3 years while goats were almost 4 years old before their growth curve leveled off.

Phenotypic correlations between weights at various ages up to 2 years are shown in Table 45. In general the correlations were better for sheep than for goats but all were highly significant for both species at all ages.

Table 41. *Analysis of variance of weights-at-age for goats in central Mali.*

Source of variation	Age (days) 0		10		30	90	150		240		365		550		730		910		1095	
	d.f.	MS	d.f.	MS	MS	MS	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS
System	1	0.0	1	0.6	4.0*	14.5*	1	65.9**	1	168.8***	1	61*	1	37	1	35	1	20	1	3
Sex	1	3.0**	1	10.6***	17.9***	88.6***	1	208.7***	1	385.2***	1	609***	1	1 739***	1	1 882***	1	2 061***	1	1 446***
Parity	3	1.9***	3	13.1***	36.9***	49.9***	3	62.5***	3	28.0*	3	20	3	14	3	6	3	18	3	22
Type of birth	1	18.3***	1	67.2***	178.5***	170.5***	1	108.1***	1	29.2	1	0	1	129**	1	178***	1	68*	1	68
Season	3	0.0	3	2.4**	6.0***	3.2	3	4.6	3	10.7	3	44**	3	7	3	26	3	29	3	27
Year	6	1.9***	6	2.0***	3.0**	9.3*	5	13.1	5	26.7*	5	40**	4	108***	4	39*	3	103***	3	31
Season x System	3	0.0	3	1.0	2.6	1.1	3	4.5	3	2.3	3	3	3	5	3	9	–	–	–	–
Season x Sex	3	0.4	3	0.9	0.9	0.9	3	1.4	3	6.0	3	6	3	5	3	1	–	–	–	–
Season x Parity	9	0.2	9	0.4	1.2	2.4	9	3.9	9	7.8	9	16	9	9	9	13	–	–	–	–
Season x Birth type	3	0.6	3	1.2	1.6	14.8**	3	34.0**	3	22.0	3	4	3	12	3	12	–	–	–	–
Season x Year	16	0.5	16	2.2***	5.0***	12.9***	15	21.2***	13	41.9***	13	23*	12	19	10	16	–	–	–	–
Error	531	0.4	531	0.4	1.0	3.4	870	6.4	709	9.0	511	11	270	17	165	15	103	16	60	18

***P<0.001; **P<0.01; *P<0.05.

Table 42. *Least-squares means of weights (kg) at specified ages for goats in central Mali.*

Variable	0		10		30		90		150		240		365		550		730		910		1095	
	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$
Overall	581	2.20	1 054	3.03	1 215	4.32	1 066	7.7	918	10.9	755	15.2	557	20.2	314	25.2	207	29.8	116	33.3	73	33.6
System																						
Millet	514	2.21	860	3.00	967	4.25a	859	7.5a	743	10.6a	614	14.6a	478	19.7a	281	24.6	193	28.7	110	32.3	68	34.1
Rice	67	2.19	194	3.07	248	4.40b	207	7.9b	175	11.3b	141	15.9b	79	20.7b	33	25.8	14	30.9	6	34.2	5	33.2
Sex																						
Female	290	2.12a	496	2.93a	576	4.20a	505	7.4a	431	10.4a	365	14.5a	309	19.1a	215	22.5a	154	25.8a	93	27.6a	61	27.0a
Male	291	2.27b	558	3.14b	639	4.45b	561	8.0b	487	11.4b	390	16.0b	248	21.3b	99	27.9b	53	33.7b	23	38.9b	12	40.2b
Parity																						
1	108	2.05a	187	2.68a	220	3.78a	183	6.9a	147	9.9a	116	14.5a	82	19.6	40	25.1	28	30.1	8	33.6	6	33.9
2	83	2.12ab	165	2.99b	188	4.29b	163	7.8b	137	11.1b	118	15.5b	79	20.9	45	25.7	32	30.2	20	34.2	12	35.4
3	82	2.30bc	140	3.20c	156	4.56	128	8.1b	110	11.5b	91	15.5b	71	20.2	37	25.2	23	29.4	10	32.9	7	31.3
≥4	308	2.32	562	3.26c	651	4.66c	592	8.0b	524	11.2b	430	15.5b	325	20.1	192	24.6	124	29.5	78	32.4	48	33.9
Type of birth																						
Single	353	2.41a	665	3.33a	797	4.78a	705	8.2a	598	11.3a	488	15.5	355	20.2	191	24.4a	128	28.6a	65	32.4a	35	32.5
Multiple	228	1.98b	389	2.73b	418	3.87b	361	7.2b	320	10.5b	267	15.0	202	20.2	123	26.0b	79	31.0b	51	34.1b	38	34.8
Season																						
Cold dry	136	2.17	244	3.18a	287	4.51a	238	7.8	206	11.1	168	15.8	124	20.0ab	72	24.2	52	27.5	34	32.9	27	33.8
Hot dry	175	2.23	296	2.87b	344	4.09b	310	7.8	270	11.2	229	15.0	159	18.8b	89	25.2	46	28.4	32	34.5	13	32.4
Rains	113	2.21	191	3.22a	226	4.60a	207	7.8	187	10.6	152	14.8	125	20.8a	72	25.9	49	31.8	30	32.1	18	32.7
Post-rains	157	2.19	223	2.86b	358	4.10b	311	7.4	255	10.8	206	15.4	149	20.2a	81	25.5	60	31.5	20	33.6	15	35.7
Year																						
1978	67	2.12ab	67	3.32a	68	4.93a	62	8.0ab	57	10.9	48	15.7ab	40	20.2ab	17	27.8a	13	31.4a	12	35.3a	11	35.4
1979	64	2.13ab	111	3.00bc	129	4.27b	123	8.2b	107	11.6	85	15.6ab	64	21.2a	40	27.0a	27	30.9a	16	35.1a	13	34.1
1980	142	1.98a	257	2.87b	294	4.20b	257	7.5ac	229	10.6	189	14.5c	137	19.1b	94	23.9b	71	28.5b	51	31.0b	39	32.1
1981	180	2.07ab	302	2.90b	322	4.25b	285	7.7ac	255	10.8	214	14.9bc	160	19.8ab	108	23.3b	85	28.3b	37	31.7b	10	33.0
1982	72	2.19b	193	3.06ac	231	4.28b	210	7.6ac	193	10.7	163	14.8bc	123	19.7b	55	24.0b	11	29.9ab	-	-	-	-
1983	42	2.69c	92	3.27a	124	4.34b	111	8.0ab	77	10.9	56	16.0a	33	21.1a	-	-	-	-	-	-	-	-
1984	14	2.21ab	32	2.82bc	47	3.99b	18	6.9c	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Within variable groups, means followed by different letters differ significantly ($P<0.05$). Variable groups without any letters did not show a significant difference in the analysis of variance.

Table 43. *Analysis of variance of weights-at-age for sheep in central Mali.*

Source of variation	Age (days)																							
	0		10		30	90	150		240		365		550		730		910		1095		1280		1460	
	d.f.	MS	d.f.	MS	MS	MS	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS
System	1	13.5***	1	132.4***	613.8***	3 113.5***	1	5 545***	1	6 138***	1	4 599***	1	2 011***	1	903***	1	337***	1	172**	1	54	1	12
Sex	1	2.7*	1	34.4***	133.7***	460.3***	1	998***	1	1 853***	1	3 408***	1	5 856***	1	3 319***	1	1 470***	1	1 067***	1	572***	1	399***
Parity	3	13.2***	3	34.2***	76.2***	144.0***	3	164***	3	71*	3	41	3	10	3	27	3	2	3	11	3	12	3	12
Type of birth	1	11.1***	1	73.6***	222.8***	308.0***	1	281***	1	169**	1	36	1	5	1	1	1	5	1	25	1	14	1	2
Season	3	1.4	3	2.6	16.9***	43.3**	3	35	3	23	3	26	3	18	3	18	3	18	3	29	3	29	3	16
Year	6	1.0	6	1.8	17.3***	58.5***	6	105***	5	84**	5	117***	5	46	4	39	4	5	3	15	3	11	2	37
Season x System	3	1.2	3	0.5	1.4	16.1	3	34	3	72*	3	41	3	10	3	46	3	15	3	36	–	–	–	–
Season x Sex	3	0.3	3	2.0	6.9	16.3	3	30	3	11	3	17	3	6	3	49	3	71	3	16	–	–	–	–
Season x Parity	9	1.3*	9	1.3	2.9	11.9	9	15	9	21	9	29	9	26	9	12	9	11	9	10	–	–	–	–
Season x Birth type	3	0.5	3	0.3	2.3	19.4	3	18	3	5	3	4	3	8	3	1	1	65	1	24	–	–	–	–
Season x Year	17	0.9	16	1.6	9.1***	39.0***	15	63***	15	66***	14	22	12	24	11	36	9	14	7	10	–	–	–	–
Error	562	0.6	a)	1.1	2.9	10.5	1 063	16	816	23	560	27	332	26	193	20	113	21	64	24	53	23	35	19

***P<0.001; **P<0.01; *P<0.05.

Table 44. *Least-squares means of weights (kg) at specified ages for sheep in central Mali.*

Variable	0		10		30		90		150		240		365		550		730		910		1095		1280		1460	
	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$
Overall	613	2.79	1113	3.87	1333	5.98	1238	11.8	1112	16.1	864	21.5	607	27.2	377	32.0	236	35.1	152	36.0	100	39.2	66	37.2	47	37.9
System																										
Millet	469	2.60a	763	3.47a	900	5.21a	821	10.0a	732	13.6a	563	18.5a	406	23.9a	268	29.0a	179	32.2a	124	33.5a	86	35.3a	58	35.1	43	36.7
Rice	144	2.98b	350	4.27b	433	6.75b	417	13.6b	380	18.6b	301	24.5b	201	30.4b	109	34.9b	57	38.0b	28	38.5b	14	43.2b	8	39.2	4	39.1
Sex																										
Female	307	2.72a	563	3.69a	684	5.66a	638	11.2a	587	15.1a	484	20.0a	384	24.6a	269	27.4a	192	29.7a	134	30.6a	87	33.1a	58	32.4a	40	33.5
Male	306	2.86b	550	4.05b	649	6.31b	600	12.4b	525	17.1b	380	23.0b	223	29.8b	108	36.5b	44	40.4b	18	41.4b	13	45.3b	8	42.0b	7	42.3
Parity																										
1	163	2.35a	253	3.36a	301	5.29a	274	10.7a	245	14.9a	187	20.5a	120	26.5	78	31.5	44	34.6	23	35.7	16	38.5	12	36.3	8	39.1
2	118	2.85b	223	3.87b	261	5.94b	240	11.8b	224	16.3b	176	21.8b	126	26.8	82	31.8	54	34.3	37	36.0	23	38.6	10	37.3	7	35.6
3	73	3.00b	159	4.09c	195	6.34c	188	12.4b	171	16.7b	129	22.1b	94	27.9	57	32.3	40	35.6	28	36.4	20	40.7	15	38.4	11	39.0
≥4	259	2.97b	478	4.16c	576	6.35c	536	12.2b	472	16.5b	372	21.6b	267	27.5	160	32.2	98	35.8	64	36.1	41	39.1	29	36.7	21	38.0
Type of birth																										
Single	563	3.13a	1015	4.47a	1224	6.94a	1145	13.0a	1029	17.3a	798	22.6a	563	28.0	351	32.4	220	35.3	144	36.5	95	40.5	63	38.4	44	38.4
Twin	50	2.45b	98	3.27b	109	5.03b	93	10.6b	83	14.9b	66	20.4b	44	26.4	26	31.5	16	34.8	8	35.6	5	38.3	3	35.9	3	37.5
Season																										
Cold dry	147	2.88	306	3.88	372	6.11b	331	11.9ab	297	15.8	211	22.6	156	27.2	103	30.6	59	36.8	41	38.4	18	41.2	17	35.2	7	39.7
Hot dry	160	2.50	301	3.66	351	5.61a	316	11.4a	294	16.4	232	21.1	175	26.3	102	32.2	72	34.7	42	34.7	20	34.9	19	37.7	16	36.6
Rains	158	3.02	275	4.24	320	6.79b	323	13.2b	278	17.3	224	21.4	159	29.1	94	33.6	57	36.6	37	35.1	33	41.2	15	39.1	11	36.9
Post-rain	148	2.76	231	3.70	290	5.42a	268	10.7a	243	14.9	197	20.9	117	26.1	78	31.4	48	32.2	32	35.9	29	39.6	15	36.7	13	38.3
Year																										
1978	102	3.07	124	4.18	135	6.86a	129	13.0a	111	17.9a	83	22.9a	65	28.7a	38	32.4	30	37.2	21	36.3	17	39.7	13	38.5	8	40.6
1979	68	2.69	106	3.97	126	6.05ab	121	12.5ab	120	17.2ab	108	22.5ab	85	27.5ab	62	32.0	44	35.1	36	37.0	33	40.7	28	36.8	25	37.3
1980	107	2.79	203	3.83	245	5.80ab	239	11.3bcd	205	15.6bc	166	20.9ab	122	26.3ab	75	32.0	56	34.8	44	35.7	29	38.2	20	36.3	14	35.9
1981	111	2.69	221	3.78	249	5.94ab	229	12.2ac	218	16.6ab	175	21.4ab	135	27.0ab	97	31.2	71	34.7	47	36.2	21	38.3	5	37.1	–	–
1982	91	2.65	196	3.86	234	6.08ab	220	11.8acd	208	15.8bc	174	20.6b	130	25.2b	88	30.3	35	33.5	4	35.0	–	–	–	–	–	–
1983	94	2.79	190	3.85	251	5.90ab	238	11.4acd	212	15.7b	158	20.7ab	70	28.5a	17	33.9	–	–	–	–	–	–	–	–	–	–
1984	40	2.86	73	3.62	93	5.25b	62	10.3d	38	13.9c	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Within variable groups, means followed by different letters differ significantly ($P<0.05$). Variable groups without any letters did not show a significant difference in the analysis of variance.

Figure 45. *Generalised growth curves from birth to maturity for goats and sheep in central Mali.*

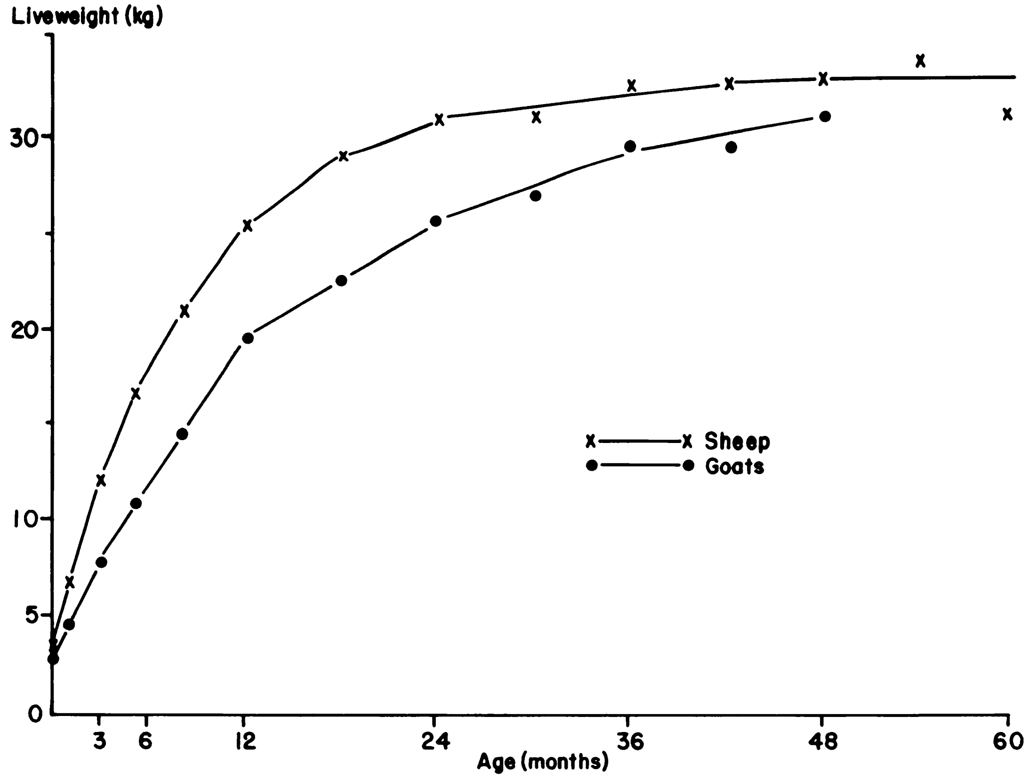
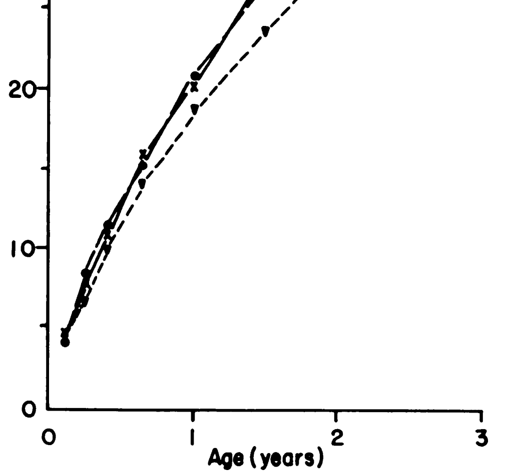


Figure 46. *Relationship between year of birth and subsequent growth to 3 years of age in central Malian goats.*



BREEDING FEMALE POSTPARTUM WEIGHTS

The observed means ($\bar{x} \pm$ s.d.) for this character were 26.0 ± 5.16 (n = 1729) for goats and 30.0 ± 5.33 (n = 1536) for sheep.

The mean squares from the analysis of variance are set out in Table 46. The weight of goats was significantly affected by the system in which they were reared, the parity (age) of the animal, the type of parturition and the season and year during which the doe gave birth. The effects of flocks within systems were also highly significant. There were also significant effects due to the interactions of season with the system, with parity, parturition type and year. In sheep, postpartum weight was affected by the same sources of variation except season and year of parturition, and, of the interactions, only that of season x system was significant.

The estimated least-squares means for postpartum weights are given in Table 47 and graphic representations of the main variables affecting them are shown in Figure 47. Weights were higher for both goats and sheep in the irrigated rice subsystem than in the rainfed millet subsystem, and in both species females that had given birth to twins (or triplets) were heavier than those that

Table 45. *Phenotypic correlations between weights at various ages for goats and sheep in central Mali.*

Age (days)	Age (days) 30	90	150	240	365	550	730
Goats							
10	0.89	0.67	0.56	0.45	0.33	0.32	0.36
30		0.73	0.62	0.49	0.38	0.42	0.40
90			0.84	0.70	0.52	0.62	0.55
150				0.79	0.52	0.62	0.55
240					0.67	0.56	0.58
365						0.62	0.73
550							0.72
Sheep							
10	0.84	0.65	0.61	0.68	0.64	0.52	0.55
30		0.82	0.78	0.74	0.70	0.64	0.66
90			0.88	0.77	0.69	0.70	0.61
150				0.79	0.63	0.62	0.53
240					0.83	0.75	0.68
365						0.80	0.74
550							0.77

had given birth to singles. Primiparous females in both species were lighter than multiparous ones, the progression being linear from first to fourth and greater parities. Goats at first kidding (82.2% of the overall mean) were relatively lighter than sheep at first lambing (87.9% of the overall mean) but both species achieved the overall mean weight by the time of second parturition.

The effects of season were rather different on the different species, goats being lightest in the cold dry season and then gaining weight in the hot dry season while sheep were lightest after a parturition during the hot dry season. The effects of year, although not significant in sheep, had similar trends in both species but the overall changes over the period of study were not marked.

Table 46. *Analysis of variance of postpartum weights of goats and sheep in central Mali.*

Source of variation	Goats d.f.	Goats MS	Sheep d.f.	Sheep MS
System	1	755.9***	1	1 350.3***
Sex	1	0.5	1	55.6
Parity	3	5 257.3***	3	2 852.8***
Type of parturition	1	154.3***	1	179.6***
Season	3	58.8**	3	22.0
Year	6	43.6***	6	5.7
Flock/millet	13	312.6***	14	411.2***
Flock/rice	5	177.4***	16	170.5**
Season x System	3	87.8***	3	60.4**
Season x Sex	3	5.0	3	20.9
Season x Parity	9	22.0*	9	18.2
Season x Type of parturition	3	40.2*	3	20.9
Season x Year	16	23.0*	16	15.8
Error	1 661	11.5	1 456	15.9

***P<0.001; **P<0.01; *P<0.05.

EFFECTS OF CLIMATE ON SPECIFIC AGE AND SEX GROUPS

Seasonal weight changes of selected age and sex groups of both species in both subsystems observed in relation to the overall mean weight-for-age are shown in Figure 48. Maximum and minimum weights in relation to the overall mean for all age and sex groups are given in Table 48. The magnitude of the seasonal effects was much less than that on cattle (as might also be inferred from a comparison of Tables 23 and 24 with Tables 41 to 44). There were no major response differences due to seasonal effects between subsystems or between species.

In general, minimum weights were observed for each sex, age class and species of stock in the millet subsystem in June and maximum weights in the post-rains period in October and November, although there was more variation in the timing of maximum weight than there was in the timing of least weight.

Table 47. *Least-squares means for postpartum weights (kg) of goats and sheep in central Mali.*

Variable	Goats			Sheep		
	n	$\bar{x}$	SE	n	$\bar{x}$	SE
Overall	1 729	25.8	0.18	1 536	31.5	0.35
System						
Millet	1 348	24.7a	0.17	1 059	29.8a	0.37
Rice	381	26.9b	0.27	477	33.1b	0.42
Sex						
Female	809	25.8	0.20	770	31.3	0.38
Male	920	25.8	0.19	766	31.7	0.36
Parity						
1	422	21.2a	0.24	381	27.7a	0.40
2	291	25.3b	0.27	293	31.5b	0.42
3	207	27.2c	0.28	218	32.8c	0.43
≥4	809	29.4d	0.18	644	33.9d	0.36
Type of parturition						
Single	1 406	25.3a	0.17	1 468	30.4a	0.19
Multiple	323	26.2b	0.25	68	32.5b	0.65
Season						
Cold dry	435	24.9a	0.29	436	31.0	0.51
Hot dry	448	25.7a	0.36	415	30.9	0.43
Rains	311	26.8b	0.29	357	32.9	0.94
Post-rains	535	25.6a	0.36	328	31.1	0.69
Year						
1978	108	24.8d	0.49	153	31.4	0.54
1979	150	26.4bcd	0.35	161	31.8	0.47
1980	389	26.5b	0.22	293	31.5	0.41
1982	308	25.9ac	0.24	262	31.5	0.44
1983	307	25.6ad	0.26	274	31.3	0.43
1984	126	25.3ad	0.36	115	31.4	0.54
Flock/millet						
Best	100	27.8	0.37	97	33.6	0.53
Worst	37	20.7	0.58	67	23.8	0.61
Flock/rice						
Best	36	29.7	0.58	4	42.8	2.06
Worst	72	24.6	0.43	14	27.8	1.13

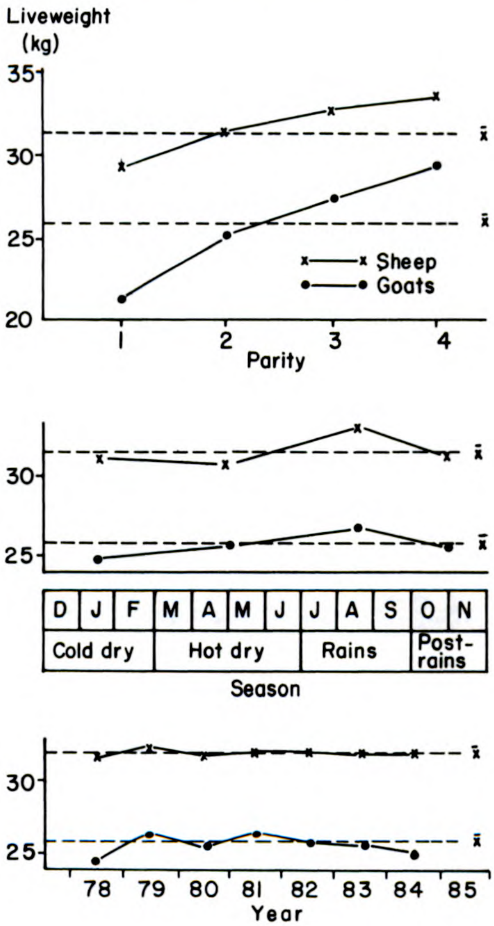
Within variable groups, means followed on different letters differ significantly ($P<0.05$). Variable groups without any letters did not show a significant difference in the analysis of variance.

In the rice subsystem there was slightly more variability in the timing of both the minimum and maximum weights. As in the millet subsystem, female goats attained maximum weights in the post-rains period, but sheep tended to be heaviest in the late cold dry and early hot dry periods, this probably being related to the availability of weedy regrowth in the harvested rice fields at that time.

Resulting in large part from the low effects of season on weight, the growth curves of goats and sheep do not exhibit the same marked type of saw-tooth pattern as that observed in cattle. Examples of actual growth curves for female sheep in the millet subsystem are given in Figure 49.

Long-term weight changes over the study period are shown in Figure 50 for mature female sheep and goats in both subsystems. Table 49 provides information on the regression coefficients of these long-term weight changes. Although, as with cattle, the general trend in mature weight has been downwards, the monthly and total losses have been much less spectacular. Animals in the rice subsystem suffered less than those in the mil-

Figure 47. *Relationships between postpartum weights and parity, season and year of birth of small ruminants in central Mali.*



let subsystem, sheep weighing 5.1% less at the end of 1983 than they did at the beginning of 1978 while in the millet subsystem sheep weighed 5.8% less. Goats in the rice subsystem actually weighed 2.5% more at the end of the study than at the beginning, but goats in the millet subsystem suffered most of all and were 9.9% lighter at the end of 1983 compared with the beginning of 1978.

DISCUSSION

The growth rates observed during this study were within the range reported for other African goats and sheep of similar mature size and are not indicative of any serious nutritional constraints when compared to the growth rates of cattle in the same environment. The gain in goats to 1 year after weaning was at 85% of the preweaning gain and in sheep at 75%: these figures compare with a post-weaning gain in cattle of only 65% of the pre-weaning gain. The effects of season on postweaning gain were not significant in sheep and, although significant in goats between 8 months and 1 year of age, these were not marked.

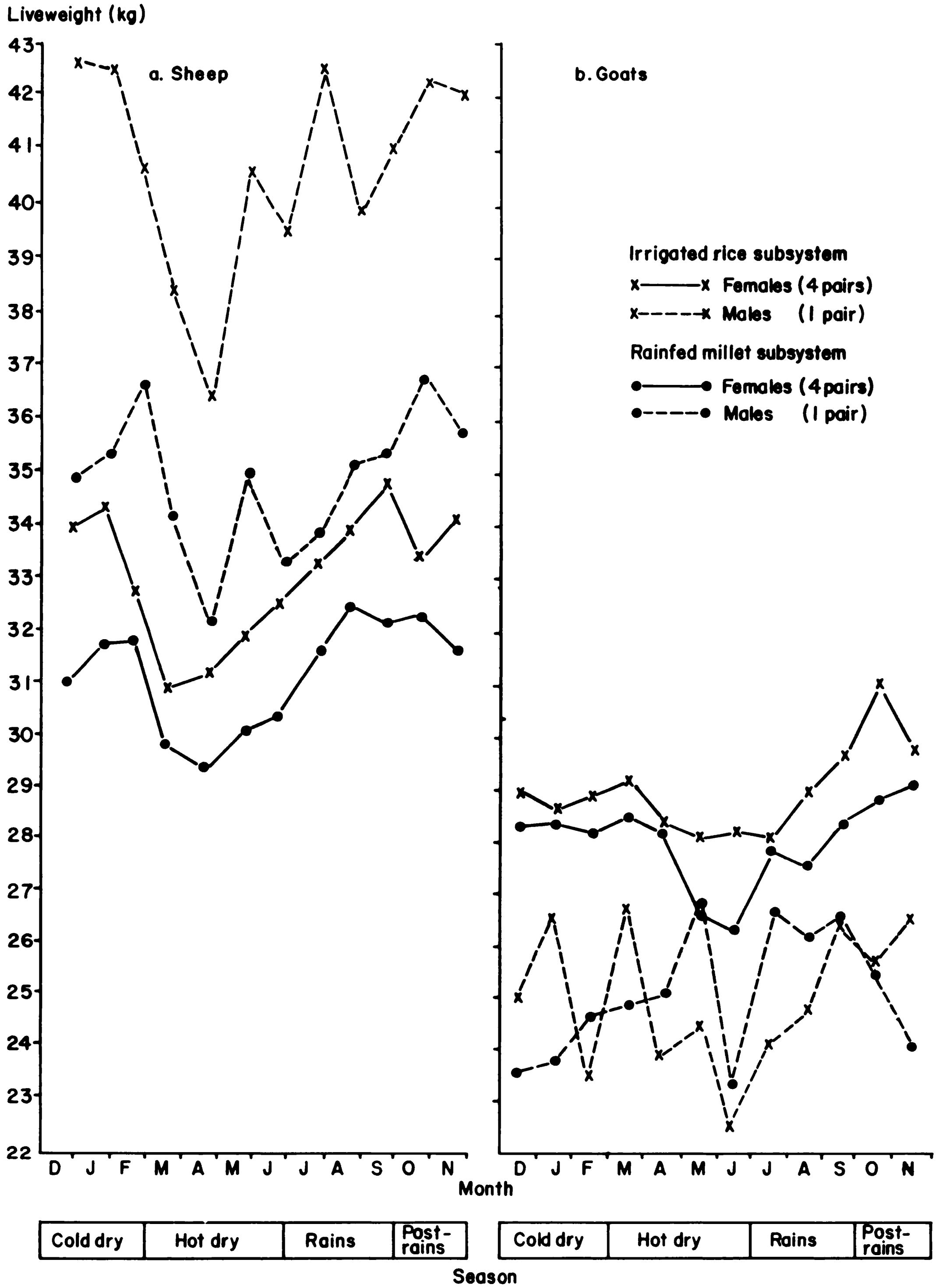
The effects of year were generally significant on weights-at-age and these can in general terms be related to the decline in rainfall and the reduced availability of total feed resources. The lighter weights at relatively mature ages (2 and 3 years) of animals born later in the study are what would be expected from the decline in weight noted for specific ages and sexes of animals in Figure 50 and Table 49. The inflection point in the growth curve occurred generally at about 12 months of age but was less marked for goats than for sheep.

Postpartum weights followed the pattern that could be expected in relation to the age of the dam. Postpartum weights in relation to the season of birth differed in pattern between goats and sheep. While maximum postpartum weights were observed in both species after a birth in the rainy season, lowest weights were noted for goats during the cold dry season and for sheep during the hot dry season. Goats presumably benefitted nutritionally from leaf development by some browse species as humidity increased during March and April. Postpartum weights as affected by season did not show the same trend as for cattle. For both goats and sheep they remained fairly constant about the mean over the 6-year study period.

The relative lack of seasonal effects on growth was also reflected in the intra-annual weight changes in specific age and sex groups for both goats and sheep. Although some weight losses occurred in all age groups due to seasonal effects (Table 48 and Figure 48), these were much less than in cattle. In general terms weights did not deviate from the mean by more than 6% in either direction for each species, sex and age group and in both subsystems. This should be compared with deviations of about 15% for female cattle and up to or more than 20% for work oxen. In practice, the effects of being reared in the rice subsystem appeared to be to delay the loss of weight in the cold dry season but there was a much less marked increase in growth rate in goats and sheep than in cattle in this subsystem due to the availability of weed growth after the rice harvest (March-April). Resulting from the less severe seasonal effects, growth to maturity proceeded with less fluctuations for goats and sheep than for cattle (Figures 48 and 35 respectively), and this applied to whatever season of year that young were born.

The long-term decline in mature weight was also much less serious in goats and sheep (Figure 50) than in cattle (Figure 36). Losses on a com-

Figure 48. *Seasonal variations in weight of corresponding age and sex groups of small ruminants in central Mali.*



parative basis were in general less than half those suffered by cattle. Both species lost less weight in the rice than in the millet subsystem.

The better adaptation of both goats and sheep to the harsh conditions of the semi-arid environment and to the generally fluctuating feed supply are clearly evident in these observations on weight. The results also show that in the medium term, the forage supply has deteriorated in comparative terms more drastically for cattle than for small ruminants.

Table 48. *Weight changes by sex and age in central Malian goats and sheep, expressed as percentages of mean annual weight.*

Species, sex and age[a]		Millet subsystem				Rice subsystem			
		n[b]	x[c]	Weight change (%)		n[b]	x[c]	Weight change (%)	
				min	max			min	max
Goats									
Males:	1	642	25.1	93.0	106.5	167	24.7	91.1	107.9
	2	380	30.3	95.6	104.6	51	30.4	93.5	108.3
	3	309	34.7	87.6	110.5	49	29.8	94.1	104.9
	4	385	40.9	96.8	104.9	14	30.8	90.9	107.1
Females:	1	1 342	20.4	91.8	105.0	218	20.9	94.1	109.3
	2	1 026	22.5	91.9	106.3	145	23.3	95.4	109.2
	3	1 300	24.9	96.2	103.1	179	26.0	96.7	105.4
	4	4 257	28.0	94.0	104.3	789	28.8	97.5	107.8
Sheep									
Males:	1	574	34.8	92.5	105.7	199	40.7	89.6	104.7
	2	221	37.7	96.6	107.3	62	45.1	91.2	113.2
	3	147	43.8	92.4	110.5	10	51.2	95.7	111.1
	4	442	45.9	96.4	104.4	–	–	–	–
Females:	1	1 159	25.7	91.7	105.3	566	29.6	94.6	102.6
	2	908	27.8	96.2	107.1	428	31.4	96.1	104.1
	3	1 090	29.7	94.0	103.8	461	33.1	94.5	104.0
	4	3 088	31.2	94.2	104.4	835	33.1	93.0	104.9

[a] Age given as pairs of permanent incisors.

[b] Number of observations in each class of stock.

[c] Mean annual weight in kg.

Figure 49. *Long-term growth patterns for female sheep born in the millet subsystem in May to June and in October to November each year from 1978 to 1982.*

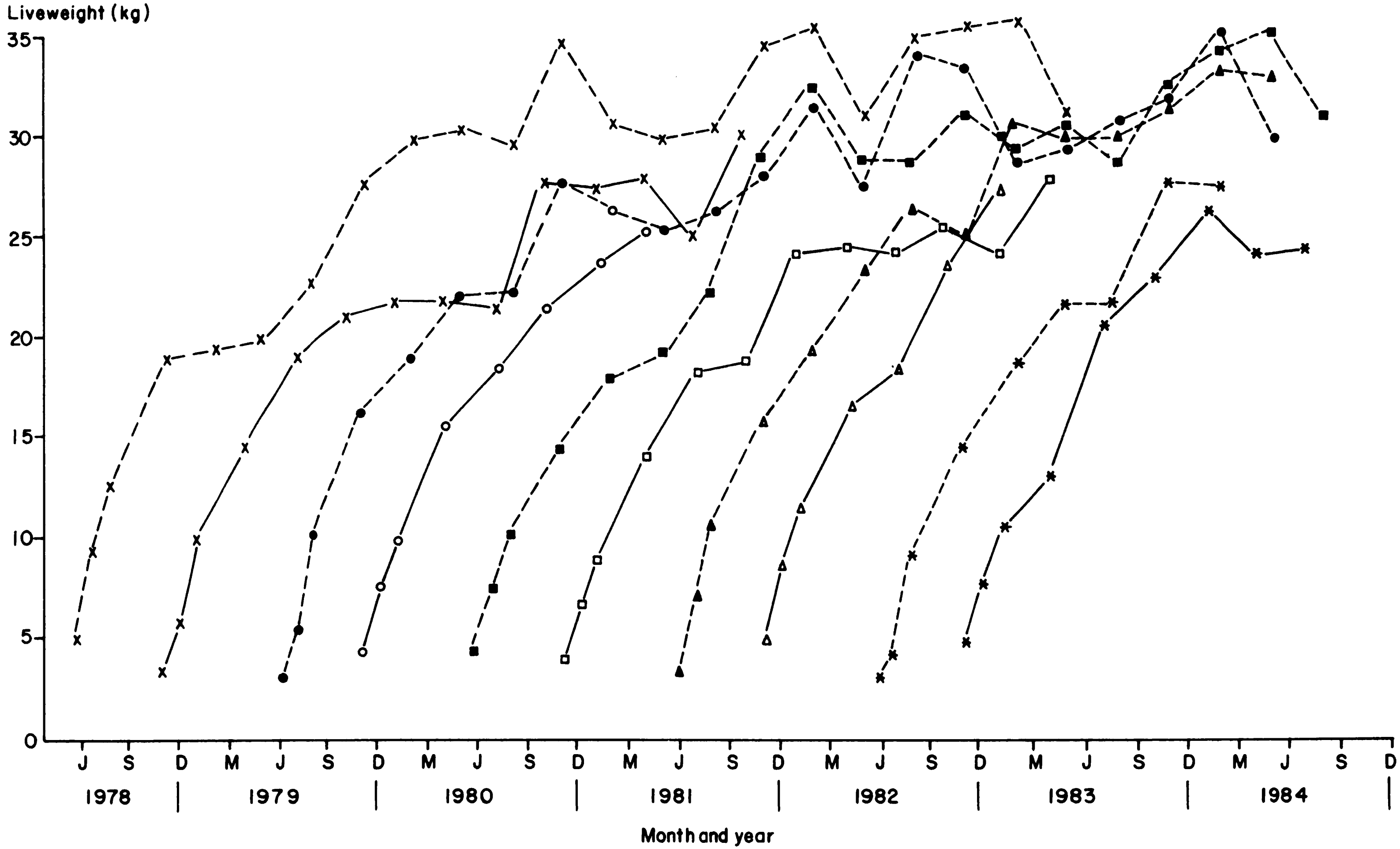


Figure 50. ***Long-term variations in weight of sheep and goats in the rice and millet subsystems of central Mali.***

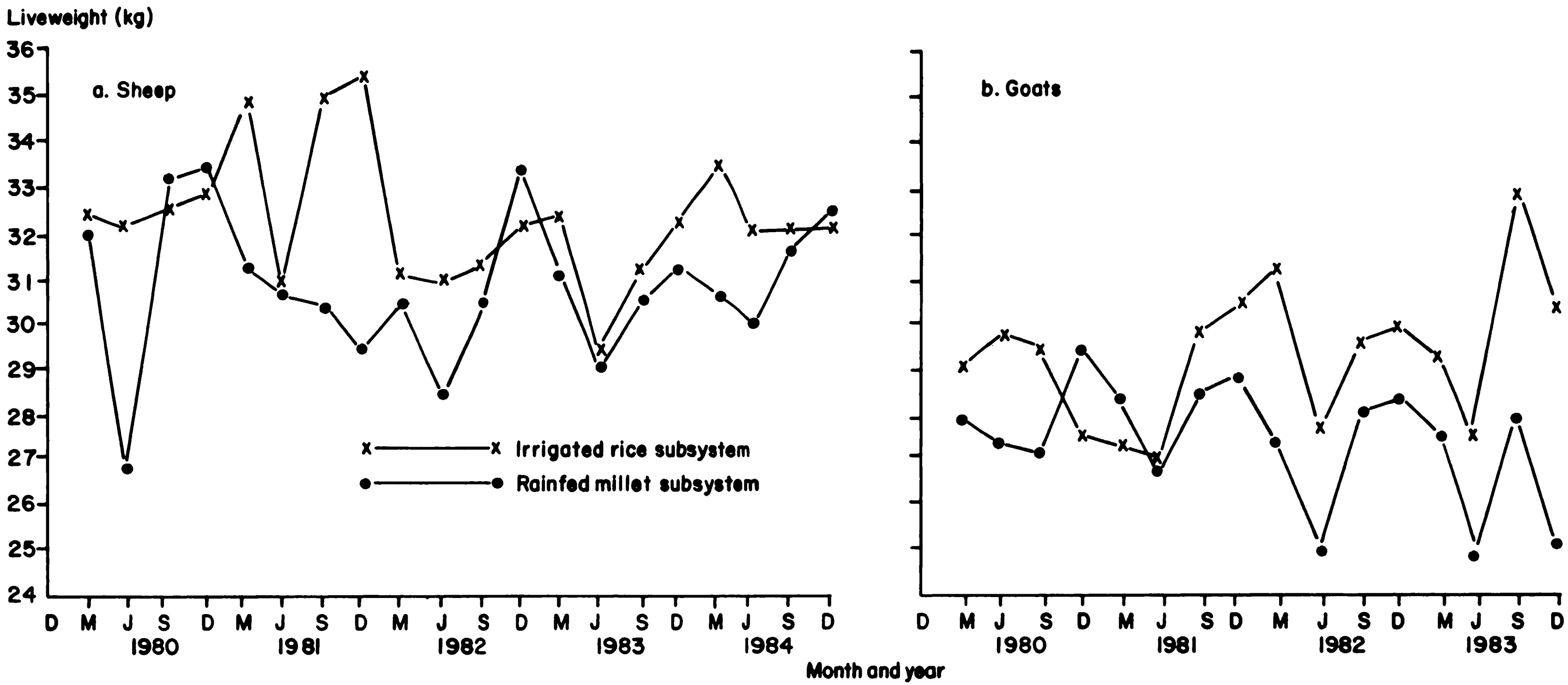


Table 49. *Regressions of weight (kg) on time[a] for mature female sheep and goats and of rainfall (mm) on time, central Mali.*

Subsystem/ species	Number of observations	a	b	r	P
Rice					
Sheep	657	−0.024	33.6	−0.0896	0.0216
Goats	789	0.010	28.4	0.0331	0.3533
Millet					
Sheep	1 727[b]	−0.026	32.1	−0.1117	0.0000
Goats	1 727[b]	−0.041	29.8	−0.1714	0.0000
Rainfall[c]	7	−33.4	452.1	−0.7871	0.0450

[a] Monthly change; intercept at December 1979.

[b] Random sample selected from 3 088 observations for sheep and 4 257 observations for goats.

[c] Intercept at January 1977 and values for years not months.

13. MORTALITY AND OFFTAKE

ABORTIONS

Abortions in goats totalled 12.6% of all births while in sheep the corresponding figure was 5.1%.

PREWEANING MORTALITY

The unadjusted mean preweaning mortality (to 150 days of age) was 34.4% in goats and 23.4% in sheep. In goats about 30% of all preweaning deaths (other than abortions) were stillbirths or occurred on the first day of life and a further 15% of kids died during the first week. In sheep some 17% of preweaning deaths were either stillbirths or first-day mortalities and a further 10% of deaths took place during the first 7 days. In goats, 66% of all deaths recorded during the study occurred before weaning while in sheep only 46% of deaths took place during that period.

The mean squares from the analysis of variance for preweaning mortality are given in Table 50. The main sources of variation influencing this parameter were the system, the season of birth, parity and flock in the millet subsystem. In goats, the year of birth had a highly significant effect and the sex of the kid also influenced the level of mortality. In sheep, the type of birth exerted a significant effect on the death rate.

Least-squares estimates of mortality are laid out in Table 51. For both goats and sheep there were more deaths in the millet than in the rice subsystem. In both species, young born in the cold dry season had a greater chance of dying than those born at other times of the year, the next highest mortality rate being suffered by young born during the hot dry season. Lowest death risk was met by young born during the rainy and post-rains seasons. In goats there was an almost linear reduction in the mortality rate from 1978 to 1983. The trend for sheep was similar although the effect of year of birth on mortality in this species was not significant. More young of primiparous females died than of multiparous dams although

Table 50. *Analysis of variance of preweaning mortality in goats and sheep in central Mali.*

Source of variation	Goats		Sheep	
	d.f.	MS	d.f.	MS
System	1	1.04*	1	0.95*
Season of birth	3	0.72*	3	0.52*
Year of birth	5	2.46***	5	0.27
Parity	4	3.15***	4	1.35***
Sex	1	0.85*	1	0.00
Type of birth	1	0.41	1	1.06*
Flock/millet	13	0.91***	14	0.58***
Flock/rice	5	0.30	16	0.27
Error	2 001	0.21	1 517	0.17

*** P<0.001; *P<0.05.

Table 51. *Least-squares means for preweaning mortality (%) in goats and sheep in central Mali.*

Variable	Goats		Sheep	
	n	x̄	n	x̄
Overall	2 035	35.0	1 563	28.0
System				
Millet	1 603	38.6a	1 067	32.1a
Rice	432	31.3b	496	23.9b
Season				
Cold dry	378	39.5a	322	32.9a
Hot dry	651	36.9ab	518	28.1ab
Rains	369	32.5bc	376	23.0b
Post-rains	637	30.9c	347	27.9ab
Year				
1978	158	51.5a	178	34.4
1979	233	35.6bc	189	27.8
1980	422	33.6bc	321	27.5
1981	456	38.7b	291	28.0
1982	411	31.2c	285	27.6
1983	355	19.1d	299	22.6
Parity				
1	429	47.9a	387	38.6a
2	307	38.8b	299	22.7b
3	258	31.4bc	222	24.2b
4	168	30.7bc	150	28.3b
>5	873	26.1c	512	26.2b
Sex				
Female	998	32.9a	800	27.9
Male	1 037	37.0b	763	28.1
Type of birth				
Single	1 375	33.3	1 432	23.0a
Multiple	660	36.6	131	33.0b

Within variable groups, means followed by different letters differ significantly ($P<0.05$). Variable groups without any letters did not show a significant difference in the analysis of variance.

only in goats was this reduction significant between the second and older parities. Sex and type of birth resulted in the expected trend in mortality, with more males than females and more offspring of multiple than of single births dying.

MORTALITY AFTER WEANING

Mortality in the period between weaning and 1 year of age amounted to only about 5% (i.e. almost 10% on a yearly basis) in both goats and sheep. The death rate after 1 year was higher in sheep than in goats, such that at 4 years of age only 30% of sheep born were still alive while 38% of goats survived to 4 years. For the calculation of these last two figures animals removed for slaughter or sale were obviously excluded from the analysis.

The mean annual mortality rate over 1 year of age was about 12.7% in goats, being somewhat higher in sheep. The trend observed in preweaning mortality rate was maintained in adult life: a greater percentage of animals died in the millet than in the rice subsystem and the death rate was higher in males than in females.

Slightly more than 17% of goat deaths were due to animals being 'lost' or taken by predators – mainly dogs – and almost 10% of deaths in sheep were from these causes.

OFFTAKE

As for cattle, offtake was calculated on an annual basis as sales plus slaughter (for social purposes or *in extremis*) plus animals gifted out permanently. The data by species and system are provided in Table 52.

Table 52. *Total annual offtake by system, sex of animals and species.*

System and sex	Offtake (%)	
	Goats	Sheep
Millet subsystem	13.8	23.5
Females	9.0	14.7
Males	38.7	45.5
Rice subsystem	26.6	34.6
Females	14.8	15.3
Males	53.1	78.7
Overall	19.3	26.8

For female goats approximately 30% of offtake was in the form of slaughter, about 8% in the form of gifts and 62% was through sales. For male goats about 39% of the animals were slaughtered, 6% were gifted and 55% were sold. Male goats were generally slaughtered before 1 year of age (63.5% of all slaughterings) while a slightly lesser percentage (52.0) was sold before 1 year of age. Females were slaughtered (39.8% before 1 year old) and sold (32.5% before 1 year old) later than males. The overall average age at offtake was about 14 months, being about 15 days earlier in the rice than in the millet subsystem and about 100 days earlier for males than for females although castrated animals were kept on to older ages than entire males. Average weight at offtake was 20.7 kg, entire males weighing about 1 kg more than females with castrates being 6 and 8 kg heavier than males in the millet and rice subsystems respectively.

In sheep about 25% of female offtake was in the form of slaughter, only 2% as gifts and 73%

as sales. For male sheep about 29% were slaughtered, 2% were gifted and 69% were sold. A similar percentage of male sheep (58.4) to that of male goats were slaughtered before 1 year old but a higher percentage (68.2) was sold before this age. As for goats, females were slaughtered (40.0% before 1 year old) and sold (44.5% before 1 year old) later than males. The overall average age at offtake was similar to that of goats at about 14 months but was very much later in the millet subsystem (16 months) than in the rice subsystem (12 months) and offtake of females in the former subsystem averaged at about 22 months compared with only 13 months in the latter. Average weight at offtake was 26.8 kg, being 24.8 kg in the millet zone (females 23.0 kg, males 24.7 kg, castrates 43.1 kg) and 29.8 kg in the rice zone (females 24.9 kg, males 31.5 kg, castrates 38.4 kg).

14. PRODUCTIVITY

MILK PRODUCTION

Few data were obtained on this characteristic. For Macina sheep under delta-type conditions at Niono, a lactation curve was established by an application of the rectangle formula for evaluating definite integrals. Data on milk yields were collected on average once per month. Lambs were penned away from their dams for a 24-hour period and allowed to suckle after 12 and 24 hours. They were weighed immediately before and immediately after suckling, and any remaining milk was hand pulled. While this method will not allow total milk production to be ascertained, it is probable that most is accounted for. All records relating to 10-day periods from parturition (1 to 10, 11 to 20 etc.) were pooled and the mean figure was assumed to be the yield at 5, 15 .... n days. Each rectangle in the lactation curve thus covered a 10-day period. The mean lactation curve and some individual yields are shown in Figure 51. Total lactation yield is of the order of 50 kg with lactation length varying from 85 to 165 days. The lactation was assumed to be completed on the day of the visit when a ewe was dry although she may well have stopped suckling up to 1 month previously: lactation lengths are therefore probably about 15 days less than shown in Figure 51 with a true mean length in the region of 130 to 140 days.

WOOL PRODUCTION

Wool was shorn twice a year to give two periods corresponding to 'wet' and 'dry' seasons. Wool production over a 3-year period is shown in Table 53. Annual yields of greasy wool at 684 g are equivalent to growth of 1.87 g/day. As might be expected, daily wool production in the dry season (1.70 g) was very much less than in the wet season (2.22 g). Males and castrates yielded more wool than females although female yields were closer to those of males in the wet season when energy and protein requirements are obviously in excess of those needed for maintenance, pregnancy and lactation.

PRODUCTIVITY INDICES

Productivity indices were constructed in the same manner as for cattle, except that weight of the litter at presumed weaning at 150 days was used as the measure of production.

The mean squares from the analysis of variance are shown in Table 54 for both goats and sheep. In general the sources of variation which exerted significant effects on the indices were the same for both species and had similar levels of significance. The sex of the young did not affect the productivity of female goats. Year effects on sheep were not significant and were relatively weak on goats.

The least-squares means for the productivity indices are laid out in Table 55. The rice subsystem had superior indices for both species. The effects of season were such that goats giving birth in the hot dry or rainy seasons were more productive than those kidding in the post-rains season, while births in the cold dry season resulted in lowest productivity. In sheep, births in the rainy season were superior in terms of productivity to those in the hot dry season which in turn were superior to both post-rains and cold-dry season births.

Productivity indices of first-parity ewes were clearly inferior to the indices of all other parities but in goats, this distinction was only evident on Index I, and when the resource-based indices II and III were calculated, the productivity of primiparous does did not differ significantly from that of second-parity females and most of those from the sixth parity upwards.

Ewes giving birth to males and twins had better indices than those giving birth to females and singles. There were no differences in goat produc-

Figure 51. *Mean lactation curve and representative yields for Macina sheep.*

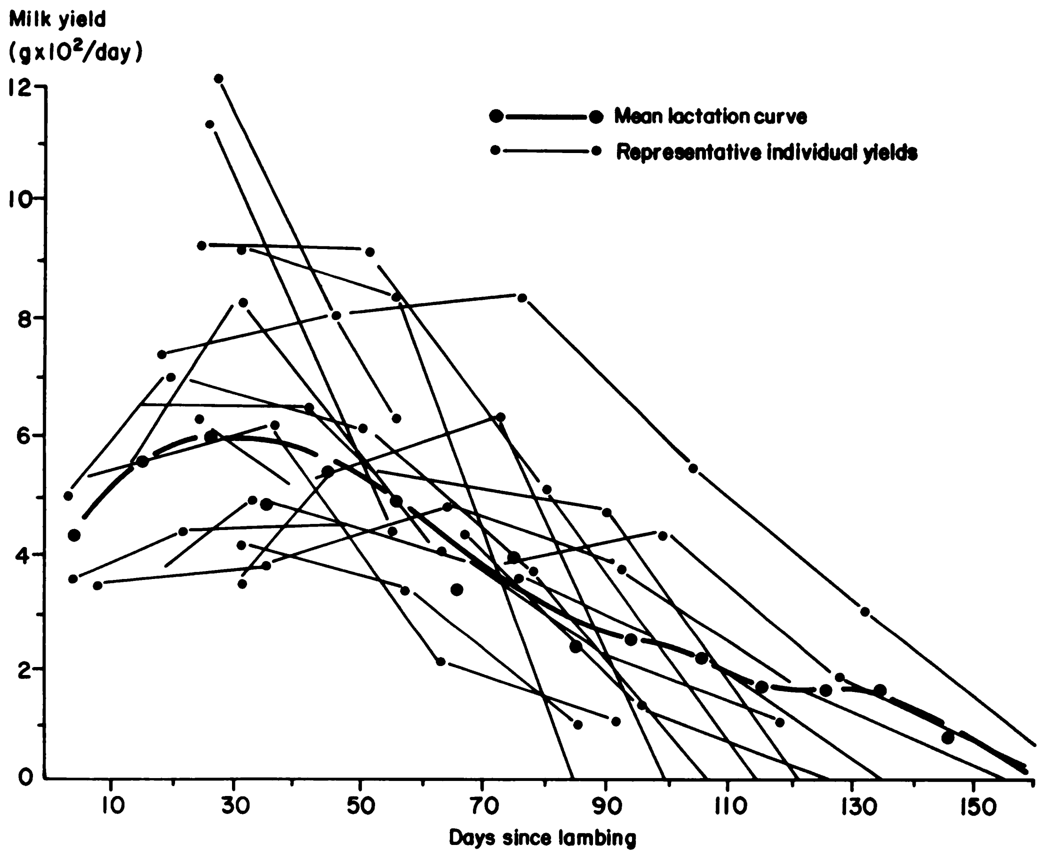


Table 53. *Mean wool production[a] by Macina sheep.*

Sex and variables	Dry season	Wet season	Year
	x̄ ± s.d.	x̄ ± s.d.	x̄ ± s.d.
Males + castrates			
No. in sample	11.3 ± 4.51	16.3 ± 6.11	13.8 ± 5.30
Total yield (g)	468.3 ± 72.86	377.4 ± 33.68	835.7 ± 52.54
Growth per day (g)	2.20 ± 0.412	2.53 ± 0.300	2.29 ± 0.245
Females			
No. in sample	27.3 ± 7.02	28.0 ± 5.29	27.7 ± 5.69
Total yield (g)	263.2 ± 73.54	281.1 ± 25.72	534.1 ± 64.98
Growth per day (g)	1.21 ± 0.107	1.92 ± 0.932	1.46 ± 0.181
Overall mean			
Total yield (g)	365.7 ± 67.86	392.2 ± 5.19	684.9 ± 42.83
Growth per day (g)	1.70 ± 0.200	2.22 ± 0.393	1.87 ± 0.119
Interval between shearings (days)[b]	216 43	151 27	365

[a] Based on 3 years' data.

[b] When shearing intervals totalled more or less than 1 year, an equal number of days was added to or subtracted from each season.

Table 54. *Analysis of variance of productivity indices for goats and sheep in central Mali.*

Source of variation	Goats				Sheep			
	d.f.	Index I	Index II	Index III	d.f.	Index I	Index II	Index III
System	1	2 619***	2.37***	15.82***	1	6 050***	4.98***	32.66***
Season	3	759***	1.33***	7.21***	3	1 660***	2.35***	13.84***
Year	5	211*	0.28*	1.63*	5	229	0.18	1.30
Parity	8	1 083***	0.55***	4.51***	7	1 848***	0.90***	7.15***
Sex	1	4	0.00	0.00	1	2 304***	1.89**	12.86***
Type of birth	2	4 308***	4.22***	27.82***	1	5 208***	3.42***	24.74***
Flock/millet	13	351***	0.36***	2.21***	13	362**	0.44**	2.54**
Flock/rice	5	1 156***	1.16***	7.42***	7	849***	0.59**	4.05***
Error	1 152	93	0.13	0.73	934	163	0.17	1.08

***$P<0.001$; **$P<0.01$; *$P<0.05$.

tivity arising from sex of young, this being most probably due to the relative lack of precocious sexual dimorphism in goats at weaning. Although twin-bearing does had indices superior to those giving birth to singles, the productivity of dams giving birth to triplets was inferior to those having twins and equal only to those giving birth to singles: this was due largely to the high death rate in triplets.

The variables acting on the productivity indices (litter weight at 150 days, mortality, parturition interval and dam postpartum weight) were correlated to the productivity indices themselves in order that comparative advantages could be calculated and improvement pathways designed.

Correlations between weaning weight and the three indices were the highest of all the characters considered (about 0.90 for both goats and sheep). Higher weaning weights would obviously lead to increased output as reflected by the indices. The figures presented are weights weaned per female, and for individual surviving young these are biased downwards by the inclusion of the zero weights of their dead counterparts. Actual weaning weights of surviving animals were in the region of 18.2 kg for kids and 24.7 for lambs. Weights of young weaned per female would therefore be increased not only by acting directly on this character but also by attempting improvement through a reduction in mortality.

Correlations between viability and the indices were high (0.72) and significant ($P<0.001$). Reducing mortality would greatly improve the indices not only directly but indirectly through higher weaning weights. Although the viability rates in this study appear to be low, they are comparable to those encountered in many other traditionally managed flocks throughout Africa (Wilson et al, 1984; 1985). Clear identification of the causes of mortality in small ruminants and reduction or elimination of these would enable increased output to be achieved over much of Africa.

There were highly significant ($P<0.001$) negative correlations between parturition interval and all three indices for both goats ($r = -0.26$) and sheep ($r = -0.36$). A shortened parturition would at first sight, therefore, appear to offer possibilities for improving total productivity. It has however been shown (Wilson et al, 1983) that in this environment intervals of less than 240 days result in a much higher mortality than intervals longer than this. Attempting to reduce the parturition interval in sheep would, then, increase productivity very little but there appears to be scope for reducing that of goats.

Correlations between postpartum weight and all three indices were positive for both goats (weight/index I = 0.36, II = 0.18, III = 0.24) and sheep (0.37, 0.14 and 0.20 respectively) and significant ($P<0.01$). Increasing breeding female weight either permanently through genetic improvement leading to greater body size or temporarily by means of strategic feeding would lead to higher indices. The correlations are the lowest of all the characters considered and more rapid improvement may arise from concentrating on improving other characters first.

Appropriate improvement paths for goats and sheep in Mali

The effects due to flock – considered here to be the basic management unit – have not yet been discussed. There were usually highly significant

Table 55. *Least-squares means of productivity indices for goats and sheep in central Mali.*

Variable	Goats				Sheep			
	n	Index I (kg)	Index II (g)	Index III (kg)	n	Index I (kg)	Index II (kg)	Index III (kg)
Overall	1 191	14.6	494	1.23	973	28.4	867	2.22
System								
Millet	934	12.1a	419a	1.04a	672	24.7a	761a	1.95a
Rice	257	17.1b	569b	1.42b	301	32.1b	973b	2.01a
Season								
Cold dry	270	12.3a	406a	1.02a	245	26.2a	784a	2.01a
Hot dry	309	15.8b	560b	1.37b	267	28.9b	904b	2.30b
Rains	246	15.9b	540b	1.34b	239	32.1c	997c	2.54c
Post-rains	366	14.2c	470c	1.18c	222	26.4a	785a	2.02a
Year								
1978	77	11.5a	392a	0.98a	95	27.9	849	2.17
1979	141	15.8b	536b	1.33b	121	29.7	900	2.30
1980	252	15.0b	500b	1.25b	204	27.4	845	2.15
1981	283	14.6b	484b	1.21b	205	29.9	911	2.34
1982	252	14.7b	506b	1.25b	203	27.2	830	2.12
1983	186	15.8b	546b	1.35b	145	28.1	870	2.23
Parity								
'0'	357	15.5ad	522ad	1.30ac	149	30.0ab	900a	2.32a
1	274	9.3b	398b	0.93b	253	21.0c	713b	1.78b
2	215	11.3c	430bc	1.04b	194	27.7a	878a	2.23a
3	151	14.0ae	495acd	1.22a	146	30.6b	939a	2.40a
4	96	15.8ad	552d	1.36c	92	29.6ab	891a	2.30a
5	54	17.4d	581d	1.46c	57	29.7ab	857a	2.21a
6	21	17.8de	548abd	1.40abc	34	29.8ab	889a	2.27a
7[a]	14	20.4d	633d	1.61c	48	29.1ab	872a	2.23a
≥8	9	9.6abc	289ab	0.74ab	–	–	–	–
Sex								
Female	601	14.5	495	1.23	514	26.8a	823a	2.10a
Male	590	14.6	494	1.23	459	29.9b	912b	2.33b
Type of birth								
Single	970	12.9a	451a	1.11a	930	22.2a	709a	1.79a
Twin	214	20.4b	685b	1.71b	43	34.6b	1 026b	2.64b
Triplet	7	10.4a	345a	0.86a	–	–	–	–

[a] '0' are unknown parities considered ≥4; for sheep parity 7 is all parities ≥7.

Within variable groups, means followed by different letters differ significantly ($P<0.05$). Variable groups without any letters did not show a significant difference in the analysis of variance.

differences among flocks for all the characters and for the three indices. The causes of these differences have not been determined although it is probable that they are related to the owner's or herder's management abilities and strategies or to his preference for one or the other species. The greatest differences in productivity are, in fact, encountered in this source of variation. If the differences are indeed related to management and the practices relating to improved productivity can be indentified and extended to other management units, overall productivity might be increased considerably. Such an improvement strategy would be appropriate to a majority of owners as it is already being practised by some with similar means of access to virtually the same resources.

The incorporation of other measures, deduced from the analyses discussed here, into an overall plan would provide an effective, integrated and cost-efficient first step in improving total productivity from small ruminants. Some comparative advantages accruing to Index II for within-variable differences are shown in Table 56. By inserting these, along with some other measures, into a sequential improvement scheme in roughly ranked order, a practical, technologically adapted programme for development can be designed.

As can be seen from Table 56, apart from overall management practices, the best results will most probably come from selecting for twinning and by attempting to manipulate demographic structure so that as many females aged 4 to 5 years as possible are in the flocks. Creating some of the conditions of the rice subsystem in the rainfed millet subsystem would also improve productivity. Controlling the breeding season so that young are dropped during the hot and dry or rainy seasons also confers considerable advantages but these would have to be carefully assessed in relation to the potential loss of productivity if births were to be limited to only one per year. The two factors over which least control can be exerted, sex of young and year, fortunately do not greatly influence productivity.

Table 56. *Ratios of comparative advantages for variables on Index II, to be used in designing improvement pathways.*

Variable	Goats	Sheep
Flock		
Best to worst millet	1.83	1.55
Best to worst rice	2.97	1.73
System		
Rice to millet	1.35	1.29
Season		
Hot dry/rains to cold dry	1.45	1.28
Year		
Best to worst	1.20	1.09
Parity		
Sixth to first	1.45	1.29
Type of birth		
Twin to single	1.54	1.44
Sex		
Male to female	1.00	1.10

PART FOUR

CONCLUSIONS AND RECOMMENDATIONS

15. CONCLUSIONS AND RECOMMENDATIONS

THE NATURE OF TRADITIONAL LIVESTOCK PRODUCTION SYSTEMS

Until recently traditional systems of livestock production have not been subjected to detailed study and analysis. Little, therefore, has been known of their productivity and problems. But this lack of knowledge has not prevented a strong corpus of opinion being propounded.

Such opinion considers, regardless of the domestic species in question, that:

- Indigenous African livestock types are of inherently poor genetic make-up;
- Nutrition is inadequate;
- Disease is a major problem;
- There is a lack of a suitable marketing infrastructure.

The proposed solutions to these constraints are, equally, of a depressing similarity:

- Importation of supposedly genetically superior stock to up-grade or replace the native one;
- Provision of concentrate feedstuffs;
- Mass vaccination; and
- Creation of a modern marketing system that is usually by inference – if not stated explicitly – state-controlled and state-run.

These hypothetical problems and solutions fail to take account of the nature and role of traditional livestock husbandry in a mixed farming system. Domestic animals in these agropastoral systems are at best an adjunct to subsistence or cash crop production. Owners are able to devote only a part of their labour to them and, across households, the amount of time given and the skill provided to stock management vary widely.

Sweeping solutions applied to all species are not likely to succeed and will not make the best use of resources, whether these be financial or natural and whether they be internal or external.

THE CURRENT DATA SET

The studies analysed and reported here are unique in semi-arid Africa. They provide data over a period of 6 years from two agropastoral subsystems and allow direct comparison of the three major species of domestic ruminants under the same environmental and management conditions. The results clearly demonstrate the superiority of both species of small ruminants over cattle in terms of meat production (Tables 31 and 55). The complementarity of the species is evident in terms of their contribution to human nutrition (Figure 39). The markedly seasonal nature of the reproductive process in cattle (Figure 29) and its inefficiency (Table 22) are highlighted and contrasted with the much less seasonal (Figure 44) and far more rapid (Figure 42, Table 38) process in both goats and sheep. The dependence of cattle on the limited grazing resources results, in the short term, in massive fluctuations in weight within a year (Figures 34 and 35) and over the long term has resulted in an alarming reduction in mature body size (Figure 36, Table 28). Goats, and even sheep, with more eclectic dietary habits, are less subject to both seasonal (Figure 48, Table 48) and long-term (Figure 50, Table 49) weight changes. In contrast to the superior efficiency of small ruminants in most of the observed parameters, their early death rate (Table 51) is much higher than that of cattle (Figure 37).

These studies did not, unfortunately, continue into the dry season of 1984/1985 which followed the disastrous rainfall years of 1983 and 1984. Little that is objective can therefore be said about response to really severe drought conditions but there is considerable circumstantial evidence, obtained from visits to the herds and flocks and through discussions with the owners, that goats and sheep suffered less severely than cattle.

MAJOR PROBLEMS TO IMPROVED PRODUCTIVITY

The results reported here have enabled the identification of the principal factors mitigating against improved productivity. In cattle these problems are:

- Poor reproductive performance as reflected in late age at first calving and long intervals between calves; and
- Nutritional stress, both seasonally and in the long tenn, leading to massive fluctuations in weight in both growing and mature cattle and overall slow growth rates which contribute to delayed sexual maturity in females and to advanced ages at which males are capable of providing draught power and being fit for slaughter.

In small ruminants the major problems are:

- High levels of preweaning mortality due to a variety of interacting causes; and
- Continued relatively high levels of mortality in sub-adult and mature stock due mainly to a seasonally recurring complex of respiratory diseases.

In both cattle and small ruminants, the differences in productivity between herds and flocks with access to the theoretically same resources indicate that the individual management ability of owners or herders could be a major constraint.

FUTURE RESEARCH

With the exception of veterinary inputs, solutions to the identified constraints should be provided, as far as is feasible, from within the existing system. With this proviso in mind, future research should concentrate on:

- Identifying management and/or socio-economic factors leading to the observed differences in flock productivity;
- Isolating the causes of the poor reproductive performance by cattle, which are probably nutritionally rather than physiologically or disease related;
- Overcoming the severe nutritional crisis in cattle by encouraging the production of fodder and forage crops, including browse species, from the agricultural component of the system, although in view of the shortfall in total feed availablity it is probable that specific target groups will need to be identified and accorded priority;
- Determining the specific causes (management, nutrition, health) of preweaning mortality in lambs and kids; and
- Developing a package of prophylactic and curative veterinary measures based on local antigens to the respiratory disease complex.

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APPENDIX

Correlation coefficients and significance levels for calves born during the 1978–83 period and rainfall at specific periods before calving.

Rainfall at months previously	Year of birth (and total rainfall (mm) in previous year)													
	1978 (384)		1979 (448)		1980 (421)		1981 (342)		1982 (364)		1983 (337)		Mean	
	r	P	r	P	r	P	r	P	r	P	r	P	r	P
9	0.5689	0.053	0.6449	0.024	0.9238	0.000	0.7730	0.003	0.7531	0.006	0.5965	0.041	0.5642	0.000
10	0.0861	0.790	0.4446	0.148	0.7586	0.004	0.6077	0.036	0.7625	0.004	0.9411	0.000	0.5634	0.000
11	−0.2573	0.419	0.0962	0.766	0.4596	0.133	0.2274	0.477	0.3428	0.275	0.3651	0.243	0.2318	0.050
12	−0.4454	0.147	−0.3729	0.233	0.1697	0.598	−0.1465	0.650	0.0995	0.758	−0.0019	0.995	−0.0195	0.871

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