WEST AFRICAN AERIAL SURVEY REVIEW.

WORKING DRAFT FOR ILCA COMMENTS ONLY
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AUTHORS' NOTE

This manuscript forms part of the first draft of a synthesis of the low level aerial surveys carried out by the International Livestock Centre for Africa and Resource Inventory and Management in West Africa between 1979 and 1985. It must be emphasised that, at this stage, it is intended for internal comment and discussion only. The individual sections have, as yet, to be fully integrated, and some of the figures are not included. Sections four is given in outline form, while the contents of section five will very much depend on the comments and discussion generated.

We emphasize that any comments will be most welcome, and should be addressed to Dr. William Wint or Dr. David Bourn, Department of Zoology, South Parks Road, Oxford, OX1 3PS, U.K.

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WEST AFRICAN AERIAL SURVEY REVIEW.

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1. INTRODUCTION.

The West African Region* occupies a total land area of some 7.5 million square kilometers and in 1980 had an estimated total human population in the order of 150 million people, with a growth rate of between 2.5 - 3.0% per annum. This implies a doubling of human population over the course of the next twenty-five years. At some 20 per square kilometer, overall population density is relatively low, but by the first decade of the next millenium it is likely to have risen to some 50 per square kilometer, about half the present population density of Europe.

It is obvious, however, that such overall figures mask considerable variation, both between and within countries, in particular human populations and natural resources are far from evenly distributed. For example, more than half the land area lies within the Sahel Zone, or is occupied by the Sahara desert: and more than half the total human population are Nigerian. It is perhaps pertinent to recall that the last officially recognised Nigerian census was held more than twenty years ago - in 1963 - and that at the time the results were hotly disputed.

Similar reservations may be held about the reliability of many agricultural and livestock statistics, for which recent detailed survey or census information is often lacking or not generally available. For instance the total West African cattle population has been estimated to be in the order of 36 million head, a third of which are to be found Nigeria. These figures are derived on the basis or various assumptions applied to such indirect measures as: tax receipts, vaccination returns, market sales and export figures, the reliability of which may also be questioned.

Another example of the general uncertainty relates to the frequently outdated information concerning environmental conditions and the changes taking place in many areas of West Africa, where recent aerial photography does not exist, or where existing cartography has not been updated. For instance, many if not most, of the topographical maps of Mali, Niger and Nigeria are based on aerial photographs taken more than thirty years ago.

Nevertheless, despite the many uncertainties and reservations that there may be in detail, some characteristic features of the West African Region and a few of the general trends taking place are outlined below.

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* Benin, Burkina Faso, Chad, Gambia, Ghana, Guinea, Guinea Bissau, Ivory Coast, Liberia, Mali, Mauitania, Niger, Nigeria, Senegal, Siera Leone and Togo.

1.1 ENVIRONMENT, CLIMATE AND VEGETATION.

The predominant landform in West Africa is that of an undulating low plateau, generally not exceeding 500 meters above sea level, with only a few relatively limited areas above 1000 meters, notably the Fouta Djallon and Guinea highlands in the west, the Jos and Mambilla plateaux in central and eastern Nigeria, and the Air and Djado mountains in northern Niger. To the west and south-west the region is drained by numerous compartively short rivers with relatively small catchment areas, while the land to the north-east lies within the closed drainage basin of Lake Chad. The area in between falls within the immense catchment of the river Niger, which rises in Guinea some 240 kilometers from the Atlantic and runs north-eastwards through Mali, almost to edge of the Sahara and then curves southwards through Niger and Nigeria to flow into the Bight of Biafra, some 4,000 kilometers from its origin.

The seasonality of climate and the pronounced north-south gradients that exist have a pervasive and complex influence on vegetation patterns, agricultural systems, livestock distribution and human society, as well as general levels of production. The wet season is longest in coastal areas, which experience a bimodal rainfall distribution, which becomes unimodal further inland. This is reflected in the progressively lower annual precipitation with increasing latitude: 2000-3000 mm in some costal areas with an 8-9 month wet season, declining to 100 -200 mm falling over 1-2 months, on the southern edge of the Sahara. Coincident with this decrease in rainfall period and amount, is an increased annual variability, with great fluctuations around the long term mean. Similarly coastal localities generally have narrower ranges of temperature and humidity both seasonally and on a daily basis, while areas further north, experience more extreme conditions. Since the Sahel drought of the early seventies there has been much debate concerning possible long term climatic change in the region and the feedback effect of increasing human impact on the environment. Various causal mechanisms have been suggested, but with such a marginal and variable climate the case remains unproven.

Vegetation in West Africa exhibits a markedly zonal pattern from coastal mangrove swamps, through evergreen rain forest, deciduous forest, xerophytic woodland to grasslands in the north. This pattern generally reflects the rainfall gradient, but is much influenced by local edaphic factors and human activity in the form of clearing, farming, burning and grazing.

1.2 ECO-CLIMATIC ZONES AND ILCA'S FARMING SYSTEM STUDIES IN WEST AFRICA.

Numerous environmental classifications have been proposed for different regions of Africa, based on various factors, or combinations of factors, including vegetation, geology, soils, altitude, climate and satellite reflectance measurements. In an attempt to provide a relatively simple unified system covering the whole continent the International Livestock Centre for Africa (ILCA) has adopted an agriculturally relevant five-tier structure, based on plant growing period, derived from the work of Higgins et al. (1978).

This classification has been described by Jahnke (1982) in his study of livestock production sytems and livestock development in tropical Africa, in which the approximate correspondence between classifications used in East and West Africa is given. The five ecoclimatic zones are: <u>The Arid Zone,</u> with less than 90 growing days, equivalent to less than 500 mm of rainfall per annum; <u>The Semi-Arid Zone,</u> with between 90-179 growing days, equivalent approximately to 500-1,000 mm of rainfall; <u>The Sub-Humid Zone,</u> with between

180-269 growing days, equivalent to approximately 1,000-1,500 mm: The Humid Zone with more than 270 growing days and in excess of 1,500 mm; and The Highlands which may have a range of growing periods, but are defined as having a mean daily temperature below 20 C during the growing period.

The approximate boundaries of these ecozones in West Africa are indicated in Figure 1. By far the largest is the Arid zone occupying some 54% of the total land area, followed by: the Semi-arid zone - 20%; the Sub-humid zone 16%: the Humid zone - 10%; with Highlands representing less than 0.1%. (Janke, 1982).

A long term process of agricultural expansion and environmental change is underway throughout West Africa. Human populations are predominantly rural and growing rapidly in size, although urban populations are also expanding. As a consequence there is an ever increasing demand for greater food production. More and more land is being turned to cultivation, and the competion for limited land resources is accelerating. Fallow periods are generally declining, and more intensive forms of agricultural production are being adopted. Communication networks are also proliferating. Natural habitats and vegetation patterns are being transformed. Traditional grazing lands are being taken over for cultivation, and pastoralists are under increasing pressure to settle and stake their claim.

One of ILCA's major roles is to bridge the gap between current understanding of the technical aspects of livestock production, and the reality of how traditional forms of animal husbandry operate in Africa today. To this end ILCA has adopted an interdisciplinary farming systems approach and established field programmes in various countries to study local production systems within the ecoclimatic zones, with a view to defining apropriate intervention strategies and testing their application.

ILCA has established four field programmes in West Africa. One based in Bamako to investigate livestock production in the Arid and Semi-Arid zones of Mali: another in conjunction with ICRISAT, based in Niamey for work in the Arid Zone of Niger: and two in Nigeria to carry out studies in the Sub-Humid and Humid zones, based in Kaduna and Ibadan, respectively.

1.3 ARABLE FARMING IN ILCA STUDY AREAS.

The diverse systems of agricultural production in the study areas can be categorized in a number of ways:

1). Oasis, savannah, forest and montane grassland agriculture.

2). Upland, lowland and irrigated agriculture.

3). Cash crop-based and subsistence agriculture.

4). Gathering, shifting cultivation and intensive agriculture.

5). Tuber and cereal-based agriculture.

Wilson et al. (1983) provide detailed material on the cropping systems in the Inland Delta of Mali and Ruthenberg (1980) provides a more extended description of these systems in relation to tropical agriculture as a whole. Gallais (1975) covers the systems of cultivation in the Gourma Region of Mali, where food-gathering is still extensively practiced. Swift (1984:631 ff.) describes the arable and agropastoral systems in the Niger Pastoral Zone; in view of the extreme climate of the area, these are surprisingly diverse. Various Land Resources Development Centre reports (1976, 1978) cover the central region of Nigeria. Powell (1984) describes the cropping systems in the ILCA case-study areas Kurmin Biri and Abet, where fallow systems are tending to give way to permanent cultivation. The sections below explore briefly some of the aspects the various areas have in common.

1.3.1 Oasis, Savannah, Forest and Montane Grassland Agriculture.

Oasis agriculture is practiced only in the Pastoral Zone of Niger, and is more characteristic of the northern part, stretching over towards the Air. It is practiced by the Twareg and the Bella, and is for the large part very intensive, making use of animal traction and irrigation to exploit the same small piece of land for many years in sucession. The date-palm forms the basis of the oasis agriculture, but wheat, barley, maize and millet are grown, as well as water-melons, okra, onions, tomatoes, pepper and tobacco. Bernus (1981:289 ff.) describes the systems of cultivation in more detail.

Savannah rainfed agriculture is practiced around the edges of the Inland Delta, on the southern margins of the NPZ and in the northern SHZ in Nigeria. In Niger it is described in Swift (1984:621 ff.) where millet, sorghum and cowpeas form the basis of the cropping cycle. In Mali, it is described by Wilson et al. (1983) and Gallais (1967), and the basis of agriculture is sorghum and millet. In Nigeria it is more diverse, with an emphasis on cereals, including maize, sorghum, millet and fonio. The use of animal manures is common, and in many areas, shifting agriculture is practiced. Tree crops, such as the locust bean (Parkia biglobosa), the shea tree (Butyrospermum paradoxum) and Canarium schweinfurthii are exploited as food supplements. Crop-mixtures are common in the sub-humid zone but become rare as the region becomes more arid.

Forest agriculture, practised in the humid zone, is also usually shifting agriculture, and depends on a mixture of tubers and tree-crops, particularly yams, cocoyams and the oil-palm. Animal manures are not normally required.

In the montane grasslands, such as the Mambila Plateau, where the rainy season is very extended, agriculture is usually not based on shifting cultivation. Either river-valleys are cropped intensively, and soil fertility maintained by the use of green manures, as on the Mambila, or else the plots are manured by cattle. Crop mixtures of varying complexity are characteristic of this type of agriculture (LIDECO, 1972 & Rehfisch, 1974:18).

1.3.2 Upland, lowland and irrigated agriculture .

Twareg farms around the desert oases in Niger are elaborately irrigated, sometimes with water that must be drawn from deepwells by animal traction (Bernus, 1981). Hausa farmers in the south of the NPZ, also create irrigated fadama gardens for onions, peppers and tomatoes.

However, most other types of irrigated farming depend on natural flooding. The Inland Delta constitutes the most significant zone of flood-plain farming with extensive and expanding rice-cultivation. This same species (Oryza gladaberrima), is also traditionally grown by Nupe farmers along the Niger where it constitutes a major staple; the Tiv began the clearing of the Benue banks for rice-fields in the 1950's. In view of the broad extension of rice in the Inland Delta it is remarkable that even today, some riverine regions of the study areas, such as the Benue above Ibi, and the Niger from Jebba to Kainji.

are little-used, partly because of the risks of trypanosomiases and river-blindness, and partly for lack of the appropriate skills to exploit them most effectively. The spread of cash-crops - such as tomatoes, onions and tobacco, that form a major element in the rural-urban trade - into the study areas is gradually accelerating, but remains at generally low levels. Certain of the montane grasslands, such as the Jos and Mambila plateaux, do have developed river-valley cropping, although the steep banks imply a rather different cropping pattern.

Rainfed upland farming is more common, and is associated with shifting agriculture and savannah ecologies. The cultigen repertoire of the Bwa farms on the borders of the Inland Delta in Mali is described by Gallais (1967, 1:282). Sorghum, millet maize and fonio are the cereal staples, groundnuts, Bambara groundnuts, cassava and chickpeas, okra, beans, pepper and edible squash. Powell (1984) describes the operation of the SHZ systems in Kurmin Biri and Abet. The principal crops are the cereals, tubers, pulses and the more traditional vegetables such as roselle (Hibiscus sabdariffa), okra (Hibiscus esculenta) and the garden eggs (Solanum spp.), with ginger grown as a cash crop. Powell (1984:6) found in Abet that 23 crops were grown in 64 cropping enterprises. Manure from cattle brought in to eat the cereal residues, and burning brushwood are common methods of restoring the fertility of the soil. Intercropping is practiced in upland regions to improve yields. Although fallowing is a traditional method of regenerating fertility in the soil, the recent availability of chemical fertilisers has lead farmers to adopt them as an additional strategy.

1.3.3 Cash-crops and Subsistence Agriculture.

Nowhere in the study areas do arable farmers depend entirely on cash-crops; the fluctuating prices for such produce would make this a problematic undertaking. However, the significance of an income from cash-crops varies with access to roads and markets, and in relation to centres of innovation, such as mission stations. In Mali, only cotton and onions are important cash-crops, although the export of rice from the Delta is increasing. In the Nigerian SHZ there are minor cash-crops, such as tobacco, sugar cane, ginger and fruit, and the market in staples, is important on a regional basis; for example, southern Zaria produces very little in the way of surplus staples whereas Niger State and the Federal Capital Territory produce staples, such as sorghum and yams, but little or no minor crops.

Subsistence agriculture remains the dominant mode of production in many regions of the survey areas, particualy the more inaccessible parts. Gallais (1967) provides household budgets for various types of arable enterprise in the Inland Delta of Mali. For Nigeria, Nadel (1941), Smith (1975) and Netting (1968) provide detailed descriptions of the type of agricultural economy north of the Niger-Benue, and Bohannan & Bohannan (1968) covers the earlier type of Tiv agriculture south of the Benue.

1.3.4 Gathering, Shifting Cultivation and Intensive Agriculture.

Populations throughout the survey zones depend to some extent on gathered foods and other wild products. However, only the Bella in Niger and the Gourma use wild foods to form an important part of their diet. The most important ishiban, or wild grains are Echinochloa colonum , Eragrostis spp. , Panicum laetum and Brachiara lata . (Twareg utilisation of Sorghum aethiopicum should also be mentioned.) In addition there is cram-cram (Cenchrus biflorus) and jujubes (Ziziphus mauritiana). No studies have been done on the relative availability of these wild foods.

The distribution of these types of production is related to the pressure on land. However, today it reflects urban and rural population expansion, especially south of the Benue. In a study of three villages in the northern study areas, Norman (1978) found that farm size was inversely related to population density. In the past, it was created by the confinement of many peoples to restricted montane habitats (cf. Netting, op. cit.). In certain regions there is a current transition between the extensive agriculture of the past to more intensive methods used today. For example, the Tiv people in south-eastern Nigeria used to be classic shifting cultivators (Bohannan, 1968). However, in the 1960's they began to adopt both irrigation techniques and a form of crop rotation (Edwards, pers. comm.).

1.3.5 Tuber and Cereal Based Agriculture.

Tubers only form a significant component in agriculture in southern parts of the SHZ. The SHZ is a region where the rainfall allows for the combination of two very different types of crop; tubers and cereals. Apart from maize, which is found everywhere except in extremely arid regions, the principal cereals grown in Nigeria, such as sorghum, bulrush millet and fonio, are associated with the semi-arid regions. Tuber-based agriculture, depending on yams, cocoyams, cassava and sweet potato, is characteristic of the humid zone.

However, with care, both types of crop can be grown in many parts of the survey areas, and thus making possible the diverse cultigen repertoires that characterise many parts of the region. Powell (1984) gives a comprehensive picture of the cropping systems in the ILCA case study areas in Southern Zaria. The expansion of the yam trade, serving both the cities and southerners living in the north, has stimulated traditional yam-growers such as the Gbari, Tiv and Mumuye peoples, to extend the regions under cultivation, and a town such as Lafia, where yams were insignificant in the market economy in the 1960's, is now a major focus ot the trade.

1.4 ANIMAL PRODUCTION IN ILCA'S STUDY AREAS.

1.4.1 Domestic Animals.

Excluding poultry, the domestic animals raised by livestock-producers in the areas under study are camels, cattle, donkeys, goats, horses, pigs and sheep the characteristics of which are outlined in the following sections.

1.4.1.1 Cattle

Of the three principal types of cattle in West Africa - Ndama, Zebu and Muturu - Zebu far outweigh the others in the regions studied. There are no Ndama in the areas concerned, and only a few Muturu in the extreme south of the Sub-humid zone in Nigeria. The principal divisions are thus between the races of Zebu cattle. Following the divisions set up by Epstein (1971) these can be broadly divided into two types: Zebu proper and Long-horned Fulani.

The principal Zebu breeds are the Twareg Zebu, the Azawak, the Sokoto Zebu (Gudali) and the Adamawa Zebu (also Gudali). The Twareg Zebu, found around the Niger bend, and brought into the Delta with the Twareg migrations, are short-horned with a black or grey coat. Azawak cattle are dark red and are favoured for their good milk yields and transport capabilities. Swift (1984:676) observes that because it has a better temperament than the Bororo cattle of the WoDaaBe, it is preferred by buyers selling for the traction market both in Niger and Nigeria. Azawak are spread from eastern Mali, through Niger and into northwest Nigeria. The Sokoto Gudali is highly valued as a dairy animal, and has a white coat and virtually no horns. Although traditionally bred in the arid and semi-arid regions in recent years it has begun to spread throughout the Nigerian SHZ, through the migrations of its principal herders the Sulebawa, a Hausa-speaking FulBe sub-group. Finally, the Adamawa Gudali is a less well-defined physical type, characteristic of the grassy uplands of Cameroun and eastern Nigeria, and may be either reddish or white.

The two principal breeds of Long-horned Fulani relevant to the study areas are the Red Bororo and the White Fulani. These are found in large regions of north-central Nigeria. The White Fulani, also known as Bunaji, and locally called Daneeji, is generally reckoned to be the hardiest breed, and has therefore been an important factor in the colonisation of the SHZ, especially in regions where population pressure has significantly decreased the tsetse challenge. The Red Bororo, also called Rahaji, and locally BoDeeji, is found in great numbers north of the SHZ, and on some of the grassy uplands. It is a larger, more prestigious animal, but has less capacity to resist disease, and is presumed to be less well adapted than the Bunaji to marginal conditions.

The use of animal traction and its failure to spread in the Nigerian SHZ has been discussed elsewhere (Blench, Bourn & Wint, 1985). However, the Twareg who come from the Air massif into the pastoral zone of Niger do use their cattle as work animals, both in drawing water from the extremely deep wells using the "tekarkart" apparatus and in levelling surfaces with the "ashek n egthri", a sort of proto-plough. Both of these are described in detail in Bernus (1981:284 ff.). In the Inland Delta, and indeed in Mali generally, more conventional animal traction has undergone a major expansion over the last three decades. This is related to both development agency extension programmes, availability of suitable oxen, together with a tendency for cultivators to invest in cattle. De Leeuw (1983:179) observes 'la plupart des familles du systeme cultural du mil dispose d'une paire de boeufs et de materiel de labour'. This process is analogous to the spread of animal traction in the Azare region of Northern Bauchi State, Nigeria, where cattle are also used to pull locally-made carts.

1.4.1.3 Camels

The dromedaries of West Africa are discussed by Doutresolle (1947), and are all derived from North African ancestors. Mukasa-Mugerwa (1981) provides a complete bibliographic review of studies referring to camels, and Wilson (1985) has produced an informative text on the subject. Camels show considerably less variation than the cattle. Although traditionally camels were classified according to their use as pack and riding animals, there has been an increasing emphasis on the meat-production in recent decades. Between 1960 & 1980 the Twareg, their principal breeders, have increasingly moved into cattle, where the environment permits, although the droughts of the 1970's and 1980's have proved the continuing value of camels as an insurance against an uncertain climate.

Wilson (1978) reports on the increasing use of camel traction in Darfur; however, there is no evidence of this trend in the survey zones. Camel-milk is drunk by the Twareg but by none of the other groups discussed. WoDaaBe often have single male camel as a pack-animal in the NPZ, but there is no evidence of a trend towards investment in camels.

1.4.1.4 Sheep

The great majority of sheep in West Africa are of a hairy, thin-tailed variety that are bred essentially for meat. They are divided into two principal types in the survey zones, the large savannah hairy thin-tailed sheep and the dwarf forest sheep. The forest sheep, known as Djallonke or Yan Kasa (ILCA, 1979) is only found in the southern edges of the SHZ. It is to a certain degree trypanotolerant, and is also resistant to footrot.

However, in the Inland Delta, a wholly different breed is found, the Macina wool sheep. Biologically adapted to the wet conditions in the Delta, it is raised as much for wool as for meat. Wilson (1983) has devoted an important study to the Macina sheep.

The larger savannah sheep is divided into a number of races, according to the principal ethnic group that breeds them. Thus, Maure, Twareg, Fulani and Bornu (=Balani) sheep are found in the survey area. Another breed that is of considerable importance is the Uda or Bali-Bali, a pied sheep of Niger and Northern Nigeria raised by specialised FulBe pastoralists. These savannah sheep are increasingly seen further south, both because of the decreased tsetse challenge, and because of the prestige of sheep in Islamic ceremonial. Only the Twareg make a consistent practice of drinking the milk of sheep.

1.4.1.5 Goats

As with sheep, goats are divided into two principal types, the black, dwarf forest goats on the southern edge of the SHZ, and the large red and white savannah goats of the arid and semi-arid regions. Although the savannah goats have been divided into races on the basis of coat colour, they form an essentially homogenous group. Larger and less trypanotolerant, they are less suitable for pastoral transhumance than sheep. This type of goat, more prestigious because of its larger size, is tending to spread further south with Islam.

1.4.1.6 Pigs

Pigs are rare in the study areas, being found only in parts of the Nigerian SHZ, and in a few Christian villages on the edges of the Inland Delta in Mali. They are either of the unimproved Iberian breed spread by the Portuguese, or else, large European breeds brought by missionaries in this century.

1.4.1.7 Horses and donkeys

Horses are now rare in all the regions surveyed, although they were once a prestigious form of transport for FulBe herdsmen in many regions. Only on part of the Mambilla Plateau are horses still bred for sale and daily use, otherwise they are kept for essentially ceremonial purposes.

Donkeys are widely used by herdsmen and in villages as pack animals in the semi-arid regions. Wilson discusses the uses of equines in Darfur, where they are still important as pack animals. However, in the Nigerian SHZ they have tended to be replaced by motorized transport, and there may be an important upsurge in their breeding in the next few years.

1.4.2 The Forms of Livestock Production.

The principal forms of livestock production within the ILCA study areas in West Africa can be summarized as follows:

1.4.2.1 Pastoral Nomadism

True nomadism is an increasingly rare form of animal production, and involves the opportunistic movement in search of pastures of graziers and their stock. It is most common in arid zones, where pasture is variable in location and must be sought every year. It depends on the ability of the pastoralist to survive economically from the dairy products and offtake of the herds. This is an increasingly problematic task in many parts of West Africa, both because the ratio of grain to milk prices has tipped increasingly in favour of grain and because herds may become too small to be viable, that is to sell stock and yet for the herd to remain stable in numbers.

It is frequently assumed that nomadic pastoralists do not farm. However, in parts of the Nigerian SHZ (RIM, 1984) there are nomadic groups that have no permanent homes, but that make small farms every rainy season on previously cleared ground. They hire local arable farmers to watch the crops as they are growing and then harvest them. These farms may move from year to year, according to the availability of pasture.

The groups of people who practice nomadic pastoralism are frequently credited in the literature with the 'cattle-complex'. In the traditional view, this meant that because of the ritual importance of cattle in their lives they were unwilling to adopt 'rational' herd management practices Sandford (1983) discusses the opposing arguments in this debate. The work of Swift et al. (1984) in Niger has shown that WoDaaBe herd management strategies tended to be very similar to the 'rational' models proposed by livestock economists. The Twareg, of course, have never been accused of having a 'camel-complex', but there is no doubt that under more favourable conditions pastoralists are willing to accumulate extremely large herds, often without strictly economic goals.

1.4.2.2 Pastoral Transhumance

In some cases, favourable conditions for stock-raisers allow them to settle without turning to agriculture and to survive on the output of their herd. This was a common situation in parts of Gongola State, Nigeria until recently (Cf.RIM, 1984). Very often, part of the herd must be sent away for a few months each year to more favourable grazing areas; in this case the presence of disease, particually trypanosomiasis, was perceived to be the principal constraint on stock production. Often, the herd will split, with the milk-herd left at the compound in the care of the older people or women, while the other animals are sent away with the young men. This type of seasonal movement is generally termed transhumance, and this type of production therefore grades into transhumant pastoralism. This type of pastoralism is becoming rarer, because of expanding arable populations, the incidence of epizootics and drought, and because of the falling price of dairy products.

1.4.2.3 Agropastoralism.

The agro-pastoralist and the mixed farmer are usually distinguished by saying that the former is a pastoralist who has taken up cropping while the latter is an arable farmer who has begun to raise stock. This reveals a certain confusion, since almost all arable farmers in West Africa keep some sort of small stock. Nevertheless, in West Africa it would appear that these two types of production are increasingly tending to converge and they are therefore not treated here as separate categories.

Blench, Bourn & Wint (1985) investigate the extent to which this has occurred in th Nigerian SHZ, and Pullan (1979) provides some data on ownership of cattle by arable farmers on the Jos Plateau. Agro-pastoralists can be broadly divided into two types; those who keep cattle as part of an integrated enterprise, and those who keep cattle economically separate. When cattle or camels are used for ploughing, for drawing water ot to manure specific fields as in parts of the NPZ, the Nigerian SHZ and the Inland Delta, then they can be said to be integrated. However, among the Samba of Gongola State, Nigeria (RIM, 1984) cattle are kept as a separate investment enterprise and not put to any use.

1.4.3 Livestock Movements.

A general rule for the movement of livestock in West Africa can be simply stated; the larger the animal the more likely it is to move and the longer distance. This is essentially because the higher nutritional demands of such stock are less likely to be satisified in a given region throughout year. Thus camels, cattle, horses and donkeys take part in long-distance movements. Pastoral sheep also move alongside cattle-herds, and in the specialised case of the Uda'en, in large separate flocks. However, even professional pastoralists often leave sheep at a stable homestead and move with the cattle alone. Goats rarely move long distances and pigs hardly ever leave the home compound.

The primary determinant of herd movement is herd size; herds of 1-5 animals can often be kept around the home-compound throughout the year and fed on a cut-and-carry basis. This is only superceded when there are substantial disease risks in leaving stock in the region of the compound. For example, the Kamuku, who are arable farmers in the Mariga region of Northwest Nigeria, own zebu cattle that were acquired from their FulBe pastoralist neibours. Because there is an unacceptably high tsetse challenge at certain times of the year, even very small herds are sent away with transhumant FulBe.

In general, however, cattle must move when their numbers exceed the capacity of pasture available to feed them. However, it is clear that the technique of bringing cattle to pasture is also implicated in this equation. In the Ganye region of eastern Nigeria, settled FulBe took their non-milking cattle away from the region for part of every dry season, to river flood-plains, sometimes a considerable distance away. However, at the same time, nomadic FulBe from further north in Bornu State, entered the region they had just vacated and passed their dry season. This suggests that pasture was available if only the pastoralist was prepared to be isolated in remote areas and to move very frequently to exploit it.

Although nomadic FulBe are often depicted as moving opportunistically, this is probably truer of those in very marginal areas, such as the pastoral zone of Niger, than in abundant regions. Ngaynaaka, the study of WoDaaBe herding by Maliki (1981), depicts the scouting for pasture, and the fluid nature of groups that move to exploit it. By contrast, in the Benue valley, 'nomadic' groups move to the same place on the sandy spits for up to eight months (RIM, 1984).

The fundamental difference between 'pure' pastoralism and transhumance is that the family unit is almost invariably split and the herd is usually split. In Nigeria, it is common to leave the milk-cows and the calves at the compound with the women and older people, while the young men take the surplus cattle to pastures.

It is generally assumed that cattle have a 'dry season' and 'wet season' disposition. However, studies in Gongola State showed that most cattle movements were essentially tripartite. During the growing season, the cattle stayed around the compound and when the dry season proper came they were moved to river flood-plains. However, in April or May, when the first sporadic showers of rain appeared, the cattle were taken further south for 1-2 months to exploit the newly flushed grass.

1.4.4 Relations Between Pastoralists and Other Productive Sectors.

Gallais (1972) is the only general review of relations between pastoralists and arable farmers in West Africa, and the rapid changes in the subsequent decades make some of his conclusions out of date. RIM, (1984) summarizes relations in Gongola State, Nigeria, and Blench, Bourn and Wint (1985) summarizes relations in parts of the Nigerian SHZ.

Generally speaking where the arable farmers are also the livestock owners there is very little conflict in the community over the management of livestock, because the means to control it are to hand. However, relations between intermittently present livestock and arable farmers, whether livestock owners or not, are often fraught. The situation is made more complex by the fact that because of the potentially valuable manure that cattle provide, considerable advantages acrue to the crop farmer who co-operates with pastoralists. Yet cattle regularly inflict serious damage on growing crops, and this is probably the most important source of conflict between these different productive sectors.

In general it can be said that overlapping modes of subsistence are more likely to generate conflict. Thus, FulBe relations with the Wurbo fishing-people on the Benue and with the Sorko in the Inland Dleta are generally good. This is because, although they have little to exchange, they are not competing for resources, since the FulBe, do not normally eat fish.

Where land is short, relations between savannah farmers and pastoralists are likely to be poor, although they improve over time. For example, in the Giwa study area in central Nigeria, where sedentary FulBe and Hausa have been settled side-by-side for more than a century, population densities are relatively high, and as a result the pastoralist' cattle must leave the area during the wet season because of the potential damage to crops. In other areas, such a demand by the arable farmers would lead to conflict, but here the Hausa and FulBe co-operate in manuring the fields and in animal traction, and this situation has been accepted.

Overall, the worst relations in the areas studied were in Gongola State, where there had been considerable conflict both in the grassy uplands and in the Benue lowlands. Common features of arable farming techniques in these areas were:

1. Farmers uninterested in pastoralist' dairy produce.

2. Farmers of a different religion to the pastoralists.

3. Farmers' crops produce few residues useful to cattle, and farming techniques inimical to the trampling that accompanies manuring.

Obviously much depends on the political power wielded by the group whose land is being subjected to pressure. For example, the FulBe wielded virtually unchallenged political authority in the Inland Delta before the advent of colonialism. During the colonial period, the leydi system was recognised, but the authorities did little to halt the expansion of arable farming. Now that power is in the hands of arable farmers, incursions into the FulBe grazing areas are increasingly frequent. However, it is hard for the FulBe to make their protest heard, especially as present conditions in the Sahel make it self-evident that arable regions are more productively employed in crop production.

The case of the Niger Pastoral Zone is somewhat contrary since the WoDaaBe pastoralists presently living there are recent migrants, who originated from the Sokoto area in the last century. Essentially, they began to exploit Twareg pasture. However, the Twareg had then and have retained political power and continue to control FulBe through access to water resources.

The conclusion is that the relations between graziers and farmers cannot be predicted a priori from the presence of specific systems of production. However, once they have been determined then there may be correlations between the seasonal distributions of cattle and crops, and the relation of the herds to the fields.

1.4.5 Livestock Production within the Overall Agricultural Sector.

The most comprehensive statistical evaluation of the place of livestock in the economy of West Africa is SEDES (1975), a review of national statistics and sales of animal products for every country. Because of the large informal sector in the livestock markets, these figures are likely to understimate the true extent of trade in domestic stock. In 1970, according to the SEDES document, four countries: Mauretania, Mali, Burkina Faso and Niger were net livestock exporters, with livestock contributing 22%, 19%, 11% and 12% of their GNP respectively. Apart from Gambia, which was considered to be in equilibrium, all other countries were net importers, with livestock production contributing 5% or less to the GNP.

The majority of all types of domestic livestock are raised by traditional techniques of management. SEDES (1975) showed that in no country in West Africa is the production of livestock on ranches higher than 8%. The disadvantage of this system is that animals are not very productive, either in terms of meat or dairy products. However, their adaption to local conditions has meant that they are hardy and able to survive preferentially in different environments. In addition, the mobility of traditional pastoral groups allows them to exploit marginal resources. The situation can be summarized broadly by saying that there are five or six specialised pastoral groups in West Africa, in whose hands the bulk of cattle and camels are found, and widespread keeping of small ruminants and pigs associated with arable farming throughout the entire agricultural zone.

Because the arid zone is largely unsuitable for arable agriculture livestock-keeping is the principal mode of subsistence of its inhabitants. These regions make an important contribution to the overall supply of animal products, partly because the ratio of consumers, who are generally the agricultural population, to producers is relatively low. However, the delicate ecological balance in these areas has meant that occasional droughts have resulted in high stock-mortality.

Traditional methods of stock-management evolved when the population of West Africa was far sparser than it has been in this century. As a result these methods have tended towards the land-extensive and to depend on free access to pasture. This is less and less the case in many parts of West Africa. Another aspect was that pastoralists could afford not to manage habitats, on the grounds that if one became unusually eroded, then another would be found. Boutrais (1972) shows that in the nineteenth century the FulBe in Cameroun systematically overgrazed the grassy uplands of Adamawa, moving gradually south in the process. Much has been said in recent years about the importance of valueing traditional knowledge of the herders. However, in many cases this knowledge is not always applicable in non-traditional situations.

1.5 FORMATION OF ILCA'S AERIAL SURVEY UNIT AND REGIONS SURVEYED.

The foregoing sections have briefly summarised the major characteristics of agricultural production systems in the areas focussed upon by ILCA. While there is a wealth of information available, much of it is qualitative, and the well substantiated quantitative data are limited largely to the results of intensive studies in specific sites.

In the late seventies, the baseline figures needed to provide a context for such studies were either non-existent, out of date, or of dubious validity. Four questions of primary importance remained unanswered: How many livestock were there in ILCA's project areas ? Precisely where were they ? What seasonal changes took place ? And how typical were the study areas of the Zones as a whole ?

Prompted by the pioneer work of East African wildlife biologists, the development of low level aerial survey techniques and the use of light aircraft to assess animal populations and monitor environmental conditions, it was decided that ILCA should establish an Aerial Survey Unit to serve its country programmes, studying livestock production systems in the Arid, Semi-Arid and Sub-Humid Zones of West Africa. A twin-engined, high wing, long endurance Partenavia 68B aircraft, fitted with an OMEGA Global Navigation System and radar altimeter, and capable of carrying upto five passengers as well as the pilot was purchased for the purpose.

In essence the aerial survey unit had three functions:

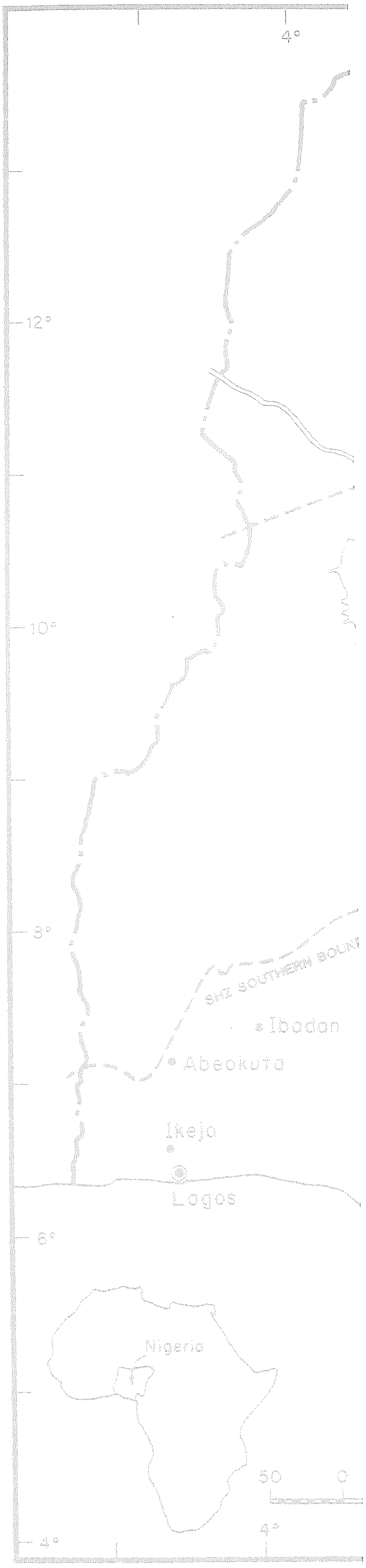
1) To adapt existing aerial survey methodology for monitoring livestock populations.

2) To provide answers to the four questions stated above.

3) To and develop and test novel applications and demonstrate their use in the West African environment.

The provision of upto date quantitative information on the distribution and abundance of natural resources in general and livestock populations in particular was considered a high priority, so that the results of intensive ground studies, which inevitably had to be of limited extent, could be placed in a wider environmental context. In the first instance the work of the aerial survey unit was confined to regions of special interest to ILCA, but subsequently surveys were carried out in collaboration with Resource Inventory and Management Limited on behalf of various national and international agencies

FIGURE 2 SUF


4°
12°
10°
8°
SHZ SOUTHERN BOUN
Ibadan
Abeokuta
Ikeja
Lagos
6°
Nigeria
50
0
4°
4°

(see Figure 1 and 2.)

It must be emphasised that the choice of survey regions was very much dependant on the requirements and interests of ILCA's country programmes and national collobarating organisations in Mali, Niger and Nigeria. The survey regions were not selected to give representaive coverage of the West African environment, but they do nevertheless span four ecological zones from the edge of the Sahara to the forest belt. All but one of the survey regions have been flown at least once in the dry season and once in the wet season. Thus the results obtained include a wide range of seasonal and environmental extremes, and because of the standard methodology employed provide a unique basis for comparison.

Two large tracts of land in the Arid Zone have been surveyed; one in the central Pastoral Zone of Niger, and the other, 500 kilometers to the west, in the Gourma region of Mali. Each was flown three times: in the early and late dry seasons and during the wet season.

The Niger survey region (NRL) covered some 81,600 square kilometers of land to the north east of Tahoua and to the south-east of Agadez and was flown in 1981/2 at a sampling intensity of 9%. Additional surveys were also carried out over the Tchin Tabaraden sub-region of the main survey zone at an intensity of 18%. Mean annual rainfall ranges from 100-200 mm in the north to 300-400 mm in the south. (See: Milligan, (1982 a & b); Swift ed. (1984); Swift and Campbell, (1984).

This region has been very recently reflown, during the wet season of 1985. To date, only the preliminary results of this work are available, and so have not been incorporated fully into this review. However, some of the major findings are briefly discussed.

The Gourma survey region occupied some 81,300 square kilometer to the south of the great bend in the Niger River between Gao and Timbouctou, immediately to the north of the international border with Burkina Faso (formerly Upper Volta) and was surveyed in 1983/4. Mean annual rainfall range from 150mm in the north-east to 600 mm in the south-west. (See: Milligan (1983); Bourn and Wint (1985); Cisse (1984)).

To the south and west of the Gourma region, straddling the boundary between the Arid and Semi-Arid Zones lies the Inland Delta region of the Niger river, upstream from Tombouctou. During 1980/81 some 35,800 square kilometers of this area in the environs of Mopti was surveyed druring the early and late dry seasons and at the start of the wet season, at a sampling intensity of 8.5%. Additional sub-regional surveys were carried out in 1982 over four selected areas of interest: Tamascheq, Cooki Nyasso, Jallube Jenneri and Yongari Mangari at sampling intensities of 17%. Although geographically in the heart of the West African Sahel, the region is exceptional because of the very nature of the Delta itself, and the delayed differential flooding that takes place over much of the area. A complex and productive agropastoral system has developed in and around the Delta, which supports substantial human and livestock popuations, as well as large areas of naturally irrigated and rainfed agriculture. (See: Milligan, Keita and de Leeuw (1982); Milligan and Keita (1982); (Wilson, de Leeuw and de Haan, eds. (1983).

To the west and almost adjacent to the Delta lies the Office du Niger region of Mali, 6,500 square kilometers of which, centred on the town of Niono, was surveyed in the dry season of 1983 and the wet season of 1984. Although in general perhaps this region might be considered to be more representative of the Semi-Arid Zone, a conspicuous central feature is the Canal du Sahel which carries water northwards from the river Niger to irrigate large areas of rice and sugar cultivation to the south and north of Niono.

The remaining aerial surveys have all been carried out in Nigeria, the most extensive of which have took place in both wet and dry season of 1982, which covered virtually the entire Sub-Humid Zone (356,000 square Kilometers), but at a sampling intensity of only 1%, in contrast to the 8 - 20% of most other surveys. (Bourn and Milligan, 1983). Two other large aerial surveys have also been conducted in Nigeria; one covering some 66,000 square kilometers of Bauchi State at the height of the 1983 wet season, to assess levels of cultivation and human habitation (RIM, 1984a); and the other covering some 44,000 square kilometers of southern Gongola State during the wet season of 1983 and the dry season of 1984 to assess livestock and land use (RIM, 1984b). Much of Bauchi State lies in the Semi-Arid Zone, while most of Gongola State survey region is in the Sub-Humid Zone, except for 9,600 square kilometer of Highlands to the south. Known as the Mambila plateau.

In addition to the Mambila plateau, another important livestock producing Highland area of Nigeria is the Jos plateau. Wet and dry season surveys over 8,600 square kilometer of this region were carried out in 1980.

Most of the other low level aerial surveys conducted in Nigeria have been more modest in scale, being restricted to relatively small ILCA case study areas and grazing reserves within the Sub-Humid Zone, individually occupying no more than 4,000 square kilometers. These surveys, which have been carried out in both wet and dry seasons, began in 1979 and have continued until 1984, with some regions being resurveyed after a five year interval.

2. METHODS USED IN LOW LEVEL AERIAL SURVEY.

Two important workshops have been held in the past to present and consider various aspects of low-level aerial survey. The proceedings of the first were published in 1969 as a special issue of the East African Agricultural and Forestry Journal, and those of the second were published in 1981 by the International Livestock Centre for Africa. Norton-Grffiths (1978) Grimsdell (1978) and Western and Grimsdell (1979) provide excellent descriptions of the methods available for counting animals, ecological monitoring and measuring the distribution of animals in relation to the environement from light aircraft.

More recently Milligan and de Leeuw (1983); de Leeuw and Milligan (1984); and Blench, Bourn and Wint (1985) have also outlined the role of low level aerial aerials surveys in pastoral research, and the integration of aerial and ground surveys in livestock production system studies. The interested reader is therefore referred to these documents for reviews and detailed discussion of the pros and cons of various techniques available and the kind of information collected. The purpose of this section is to consider briefly the basic philosophy of the sampling strategy adopted, outline the techniques employed by the ILCA Aerial Survey Unit operating in the West African environment over the last six years, and to give an indication of the development of the methodology and the breadth of information obtained.

2.1 BASIC METHODOLOGY AND ITS DEVELOPMENT.

2.1.1 Sampling Strategies.

The arguments presented below are condensed from a recently commissioned review of the statistical and sampling methodology used in ILCA/RIM aerial surveys (Marriott and Wint, 1985).

Given that the primary aim of aerial surveys is to provide details of abundance and distribution, there are theoretically four types of sampling that could be used. These are quadrat samples, point samples, line intercepts, and strip samples. The first three of these are not suited to aerial survey work, as they involve either considerable amounts of access flying and pinpoint navigation, or an urealistically precise degree of sample definition. The last is well suited to aerial survey, as it is comparatively easy to define a sample strip of known width, and to fly at a constant height in a straight line.

Sample strips can be flown at random directions and intervals, or in regular intervals, and then observations recorded on successive fixed lengths. This latter strategy has the effect of creating a regular sample lattice over the survey area, with separate records for each unit or grid cell. The observations on a cell are regarded as representative of conditions at the centre point, so that subsequent analyses can treat the cells in the same way as a point sample.

Once grid cell sampling has been chosen, three questions have to be considered: - whether to carry out random or systematic sampling; whether or not that sample should be stratified; and what constitutes an independent sampling unit.

A systematic sample from a patchy population ensures that all parts are represented in nearly the right proportions, whereas a random sample my fall in areas of high or low density more often than the proportion of such areas in the population would suggest. Further a systematic sample provides more or less constant accuracy throughout the sampling frame, unless there are regular and periodic structures in the population. This is extremely unlikely to be the case for any natural system. The major consequence of choosing a systematic sampling pattern is that the calculation of the error term is somewhat more complex. This is discussed in section 2.2.

As far as stratification is concerned, that is the sampling of different sectors of a survey site at different intensities, there are arguments both for and against. The points in favour of stratification are essentially that areas with low populations can be sampled at low intensity, while those with high numbers can be covered more intensively, and thus with greater precision. This however presupposes some advance knowledge of the distribution of a population within the survey site. It is also complicated by the very real possibility that different parameters have different distribution patterns. The choice of a particular stratified strategy might for example increase the precision of, say, cattle population estimates, but would have the reverse effect as far camels are concerned. Similarly stratification in favour of cultivated land would adversely effect estimates of woodland or forest. Thus, if the provision of overall distribution maps and population estimates for a range of parameters is required, then all the advantages lie with unstratified sampling.

The definition of the independent sample unit relevant to grid cell sampling has been discussed for several years, and essentially two choices are avaiable: - either the individual grid cell, or the flight line consisting of the entire sample strip, with each observations from each grid cell constituting a replicate measure. It has long been thought that individual grid cell observations are non-independent, because populations are oten clustered to some degree. However, the evidence of Yates (1981) and others, as discussed in Marriott and Wint (1985) suggest that grid cells can, and indeed should be treated as independent samples, particularly if flight lines have been inadvertently oriented perpendicular to the main direction of variation.

In view of these arguments, the basic technique adopted in all the ILCA/RIM aerial surveys of livestock habitation and land use has followed standard procedures of Systematic Recconnaissance Flights (SRF), described by Norton-Griffiths (1978), in which a series of parallel flight lines are flown over the given region at an equal distance apart. Each flight line is divided into sectors of equal length to form a sampling grid, based on the UTM projection. The size of each cell depends on the desired sample intensity for each particular survey. Two grid cell sizes have been commonly used: 5x5 kilometers, or 5x5 minutes of latitude (9.2x9.2 kilometers), which result in sample percentages of between 5 and 20% according to flying height and strip width.

As will be evident from the arguments presented above, the surveys have employed a systematic and unstratified sampling strategy, whereby the aircraft is flown along the centre line of each grid, and observations made from a fixed sample band. The survey region is thus covered uniformly, so that the data collected is immediately mappable, and relatively easy to interpret. After the surveys have been completed, the information is analysed in relation to a range of strata which may derive from the records made during the survey, or from information obtained from ground survey, or extracted from previously published maps.

2.1.2 Precision and Accuracy of Aerial Survey Estimates.

A distinction is often made between precision and accuracy of an estimate. Precision refers to the repeatability of the result; if repeated samples, using the same technique give closely similar results, then the precision of the method is high. Accuracy refers to the variability of the result about the true value. If a particular method counts only 10% of animals of a particular species, but counts that proportion quite consistently, it may give estimates of high precision, but obviously very low accuracy. High accuracy implies high precision, but a biased estimate may also have a high precision despite being of low accuracy.

In practice, the standard errors attached to estimates refer to the precision rather than the accuracy. Of course biases are avoided as far as possible, or corrected by an appropriate adjustment (see section 2.1.3), but the final value assumes that bias has been eliminated. A confidence interval, by definition, has a certain probability of including the true value, but the calculation cannot take account of unrecognised bias.

The distinction is important in some, but not all contexts. A biased estimate of total population size, or of total area under a crop is misleading, and it must be realised that the error attached to the estimate assumes that bias has been effectively removed. Biased estimates of high precision can, however give estimates of the changes between successive samples, and maps based on such estimates can give good estimates of relative densities of animals or crops. In such cases the bias at least tends to cancel out.

2.1.3 Visual Assessment.

On board the survey aircraft, as well as the pilot, there are usually three experienced observers. The front seat observer who sits alongside the pilot is responsible for: determining flight line waypoint coordinates; maintaining accurate navigation by identification and location of recognisable ground features; recording flight details such as height above ground; informing the other observers at the start and end of each grid; and recording selected environmental characteristics of each grid. The responsibility of each of the backseat observers is to examine a strip of ground on his side of the aircraft and to record the type and number of animals/dwellings of each category seen within, and only within his ground strip. The strip on each side of the aircraft is defined by an externally mounted viewing frame, which is adjusted prior to any survey to give the desired strip width and hence sampling intensity, at a predetermined flying altitude.

As well as recording what he sees, each back seat observer has an automatic 35 mm Nikon F3 Camera with a 200 mm telephoto and is required, wherever possible, to take photographs of all herds or settlements in excess of ten falling within his ground sampling strip. Comparison of subsequent accurate photocounts with the estimates recorder by observers during survey allow an individual counting bias to be determined which is used to correct those estimates for which clear photographs were unavailable.

In addition to this essentially visual assessment of resources by observers with selected oblique photography the aircraft can act as a pltaform for other remote sensing devices, such as cameras or radiometers. A technique of vertical sample photography has also been developed and used either on its own or in conjunction with observers, depending on the nature and requirements of the particular survey.

2.1.4 Vertical photographic assessment.

Systematic recconnaissance flight sample vertical photographic coverage has been obtained over two large survey regions: the NRL/ILP pastoral zone of Niger and Bauchi State, Nigeria, as well as more limited areas of Mali.

The scale of a photographic negative or transparancy taken vertically above the ground is equal to the focal length of the lens used, divided the height above ground measured in the same units. Thus at 800 feet with a 24 mm lens the scale of a 35mm transparancy is approximately 1:10,000, which can be enlarged by projection as required, e.g if blown up to 1.8 m the resultant screen image will be 1:200. At the same height using a 200 mm lens the scale of the transparency will be approximately 1:1,200 and the projected image would have a scale of about 1:25.

The ILCA Partenavia has been modified for vertical photography by the provision of a trap-door on the floor of the aircraft, over which a camera platform can be mounted. One or two Nikon F3 cameras with 250 exposure bulk film backs and motor drives can be bolted to the plate and fitted with a variety of lenss as required. In addition each camera has its own data back for recording date and time to the nearest second, and an intervalometer for triggering frame exposure at intervals ranging from tenths of second to hours. The frequency of photography being dependant on a combination of lens focal length, flying height and sampling intensity required. Both cameras can be used simultaneously, one to give the wide angle view and the other to provide detailed telephoto coverage. Stereo pairs can also be produced.

Black and white, colour or infra-red film can be used as required, but in recent work 200 ASA Ektachrome professional colour slide has been used. If photographic rate is high and 500 frames are inadequate, film changes are necessary in flight, which requires the presence of a photographer or special training of an observer.

Subsequent photointerpretation of print or slide material allows for direct counting or measurement of objects within each frame and determination of absolute density or size. Alternatively a random or fixed array of sampling points on an overlay or projection screen enables the proportion of various ground cover or land use categories to be determined.

The essential advantage of vertical photogrpahy is that a permanent record is obtained which can be interpreted in detail and at leisure, or reinterpreted at a later date for additional information as required. The major disadvantage is that at the relatively low level that surveys have been carried out, very large numbers of photographs are required to obtain a reasonably large sample size.

2.1.5 Radiometric Assessment.

In 1984 a low level aerial radiometry programme combined with simultaneous photography was initiated in Mali and subsequently extended to Niger. This work formed part of the validation process for the interpretation of satellite imagery and expanding the coverage of ground based measurements, in order to test the feasibility of developing a Drought Early Warning System. For this purpose the camera platform was modified so that a four channel radiometer could be mounted along side the cameras. The radiometer was connected to a data logger, programmed to trigger the the scanning process at the desired frequency and store either, individual radiometry values, or calculated means and standard deviations over selected time intervals.

2.1.6 Development of Methodology 1979-1985.

During the last six years, ILCA and RIM personnel have adapted and expanded the basic aerial survey methodology, as initially developed for wildlife counts in East Africa, in a variety of directions. The major avenues have been: an expansion of the parameters recorded; the extension of the aerial survey methodology to include the measurement of cropping patterns, and potentially, selected aspects of forestry; the visual presentation of the results; the evaluation and statistical analysis of the information collected; the planned integration of ground and air survey; the scale of the areas surveyed; the uses to which the data are put; the use of aerial survey to identify sites for potential development options for interventions identified on the ground; the quantification of the target populations of the development options identified; and the use of ground and air data to estimate populations otherwise inimical to air survey methods.

The actual parameters recorded initially consisted of those strictly describing the levels of livestock, arable and pastoralist farmers populations,as well as land use and environmental conditions. The livestock counts made have changed little since 1979, bar an increased emphasis being placed on the types of cattle seen, should it have proven necessary as in southern Gongola.

Since 1983, the arable farmer populations have been estimated using habitation rather than compound numbers, and for a short period, the wealth of the agricultural population was assessed by recording the ratios of tin to grass roofed dwellings. This last measure has been subsequently abandoned because the number of tin roofs is likely to reflect the rainfall levels, and the local availability of corrugated iron sheeting, as well as the amount of surplus cash available. Another recent development in this area is the division of pastoralist habitation into purely pastoralist and agropastoralist categories, based on the presence of adjacent cultivation and cattle corrals. Further division of the arable and agropastoralist farmer dwellings into ethnic groups is now under consideration, as each group is likely to practise specific husbandry techniques, and information about the distribution of differing husbandry practices would prove an invaluable aid to assessing the local applicability of individual development interventions. Such a fine resolution of agricultural dwellings presupposes a close link, at the start of an aerial survey, between exploratory photographic ground teams and the aerial observers and photointerpreters.

In terms of the environmental and land use parameters, the more recent aerial surveys have recorded degree of topographic dissection, various categories of access, erosion scores, amount of burning, and cattle trails and their direction, in addition to the basic estimates of grass cover, vegetation category, water availability and cultivation levels.

The use of aerial survey to assess cultivation patterns in West Africa has been extended considerably in recent years, using small format (35mm) vertical photography. A experimental RIM survey in conjunction with APMEPU has demonstrated that, by dint of taking both wide angle and telephoto photographs of the sample strips within each grid, it is possible to estimate not only the overall percentage cultivation, but also the proportions of many of the most widely grown crops and crop mixtures.

However, several factors affect the accuracy of this procedure. The exact timing of the flights in relation to the maturity of millet, sorghum and maize determines the degree to which these crops can be distinguished apart; also the flights should avoid early morning and late evening so as to minimise the amount of shadows which, if excessive, may make crop identification difficult. Finally, the use of telephoto photography while necessary for identifying crop types, severely limits the sample intensity, so that a compromise may be desirable between photographic resolution and sample coverage.

This photographic technique has the potential for being used to estimate tree cover and even standing timber volumes, if a degree of ground truthing is available to first link crown measurements with timber volume. This possibility has been treated in detail by Keppel Palmer, Speight and Wint (forthcoming).

As the West African Aerial Survey Programme has progressed, it has become increasingly evident that a considerable amount of the potential value of air surveys has remained unexploited because of the lack of adequate complementary and integrated information from the ground. Such information, if collected at the same time as the aerial estimates, has proved invaluable, not only to explain specific or apparently anomalous local distribution patterns, but also to validate any interpretations of the aerial surveys. For example, is a fall in cattle numbers within a particular locality the result of mortality, seasonal or longer term emigration, or merely the departure of temporary immigrants?

The potential value of ground investigations that are fully integrated with preceding aerial surveys has been demonstrated by the southern Gongola Livestock and Land Use survey carried out in 1983 - 1984. In this study, the primary locations for ground studies were first identified by an aerial survey, thus reducing the amount of time and manpower needed to adequately cover the major sites of cattle concentration. Once targetted, the ground team then collected a wide range of information covering husbandry techniques; herd structures, large and small livestock ownership patterns, offtake and mortality figures; details of the constraints acting upon local livestock production, as perceived by the pastoralists themselves; and the stock-owners opinions of the acceptability of the available development interventions. From these it was possible to formulate a range of possible development options specific both to the study area as a whole, and to sub-sections of it, that were designed to promote livestock production.

The data collected on the ground were then re-integrated with the numerical estimates and distribution patterns obtained from the aerial survey to provide a wide variety of information that was not available from either survey alone. Some examples are: the size of the target livestock populations potentially susceptible to each development options; the possible locations for specific development interventions based on the environmental, sociological and demographic characteristics of each sample grid cell; the overall size and distribution of livestock populations that could not be counted from the air, such as goats; macro-economic descriptions of the livestock sector within the survey area, based on stock prices and numbers.

The integration of air and ground surveys thus allows for the much wider use of the otherwise purely numerical information collected from the air, particularly in relation to the identification, targetting and evaluation of possible development options over a large geographical area. Such information provides an invaluable basis for the process of project identification and appraisal, and can also be used as baseline data for subsequent monitoring and evaluation.

2.1.7 Parameters Recorded.

A summary of the actual and potential information that can be obtained from Sytematic Recconnaissance Flights is given in Table 1.

2.2 DATA PROCESSING.

2.2.1 Data Analysis and Statistics.

There are essentially two types of raw data that are collected from the air:- variables that are estimated once per grid, and those for which several records per grid cell are obtained. The former comprise the estimates made by the front seat survey coordinator, such as altitude, water availability or grass cover, and in non-photographic surveys, percentage cultivation and vegetation type. They also include information extracted from published maps, such as altitude, land system or distance to the nearest road. The multiple entries per grid square include livestock and habitation numbers, from observer or photographic records; and from photgraphic survyes only, counts of cropping levels or stand densities. More recently, radiometric measurements have also been incorporated into the datasets, as either multiple readings per grid or single mean values with associated standard deviations.

Once the raw data has been corrected for bias, and for variations in altitude, a single value for each parameter is calculated for each grid cell, and entered into a rectangular dataset, (consisting of row and columns which represent individual grids and variable values respectively). It is on this that the the majority subsequent analyses are performed. Such datasets are, perforce, relatively large, with up to 40 variables per grid cell, and as many as 2,600 grids per survey. Therefore the great bulk of the analyses has in the past been performed on mainframe computers. Two have been regularly used - the VAX11 and the HP3000. Only recently have extended micros become available that can handle the volumes required sufficiently rapidly, and to date, only the HP150 has been used for West African aerial surveys.

Before analyses can be undertaken, it is first necessary to decide whether any variables should be transformed in order to normalise the frequencies of, for example percentage figures, or to reduce the influence of extreme values. Given that extreme values, be they high or low, are often of interest, it has been considered generally undesirable to mask their effects, and thus transformations of the data have not, as a rule, been performed.

Two broad categories of analyses are normally required - the estimation of overall and sub-population levels together with their standard errors; and bivariate or multivarite analyses designed to identify the interrelationships between the various parameters measured.

The calculation of population estimates is basically a matter of multiplying the recorded numbers by the inverse of the sampling percentage. However this does not provide any indication of the precision of the estimate. Until late 1985, the calculation of standard errors relied entirely upon the Ratio Method described by Jolly (1969) (see Appendix), as originally used for wildlife surveys in East Africa. This method treats each flight line as an independent sample of the true population, and calculates the variance between each flightline.

TABLE 1. PARAMETERS ESTIMATED FROM THE AIR.

SURVEYS WITH HUMAN OBSERVERS

WITHIN THE SAMPLE BAND

NUMBERS

Animals

Cattle, Cattle Colour Type, Pastoralist Sheep, Horses and Donkeys, Camels, Wild animals

Habitations and Settlements

Arable, Agropastoral, Settled/Transhumant Pastoralist, Settled/Transhumant Pastoralist with associated crops, Nomadic Pastoralist, Fishermen's, Ethnic Groups, Tin and Grass roofs, Villages

Other

Deserted Corrals, Tar Roads, All Weather Roads, Tracks Deserted Settlements and Habitations, Rivers and Open Water, Wells

WITHIN EACH GRID

Presence/absence of Open Water, % Cultivation, % Burned Ground, Gully and Sheet Erosion (0-5) % Closed Canopy Forest, % Open Canopy Woodland, % Savanna Woodland, % Grassland, Flying altitude, Grass cover (0-5), Indicator Species

PREDOMINANTLY PHOTOGRAPHIC SURVEYS

WITHIN EACH PHOTOGRAPH *

NUMBERS

Habitations and Settlements

As Above

Cropping and Cultivation

Percentage of area in current cultivation cycle, Percentage of area lying fallow, Proportion of identifiable crop species, Stand Density, Land Preparation, Cultivation Type

Environmental

Presence and type of surface water, Presence and type of access route, Degree of erosion, Radiometry Values, Bare Ground, Grass Cover, Tree Density

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The parameters described are not intended to provide an exhaustive list of the possibilities, but rather represent those which have been estimated in previous RIM surveys.

There are, however, considerable drawbacks with the Ratio Method, particularly when associated with systematic transects of the sort used by the Aerial Survey Unit. Most important of these is the fact that the size of the standard error reflects the patchiness of the population, rather than the errors inherent from the sampling pattern, or counting bias. This is because, in such patchy populations, the number of animals recorded in two adjacent populations may be very different, one line being over a focus of population, and the next one missing it.

In order to avoid such problems, and as long as a systematic sampling strategy is used, it is possible to use an alternative technique to produce an estimate of the error of the calculted population total. This is based upon assessing the difference between the value recorded in each grid cell and those from its immediate neighbours (Marriott and Wint, 1985). The resulting error term is still likely to be conservative, i.e it will overestimate the error due to random effects, but will be less sensitive to large scale patchiness in distribution pattern.

The number of neighbours used to calculate the variation between grid cells can obviously range from 2 to a maximum of 8, as the outliers must be symmetrically placed about the central grid. However, the more neighbours incorporated, the more complex the calculations, and further, the lower will be the proportion of grids that will actually be bordered by the requisite number of squares. The number considered to be adequate for the present purposes is four, and the resulting formula isgiven in Appendix .

Even if only four neighbouring grids are required to provide the relevant error estimate, this still limits the number of grid cells that conform to the criteria within a survey area. For example, the cells along the edge of a survey site will not have four symmetrical neighbours. Thus this method relies on the calculation of a mean grid value from the whole survey area, but a variance estimates of only a subsample of grids which is assumed to apply to all cells.

Thus the precision of this error estimate will depend to some extent on the size of the survey site, which in turn will determine the proportion of grids with the requisite number of neighbours. This is discussed further in Marriott and Wint (1985) who reach the broad conclusion that, ideally, this method should be restricted to areas of 1,000 square kilometers and above.

A disadvantage of this new technique is that it will only provide standard errors for spatially discrete areas. Thus it is applicable to stratifications such as administrative areas, but cannot be applied to strata where grid cells are not contiguous. Another such example is grids with more than a certain percentage of cultivation, which are likely to be widely dispersed throughout a survey site, and so each grid would be unlikely to be bordered by four symmetrical neighbours.

Therefore, future analyses should incorporate both the Marriott and Jolly standard error estimates, the former for general use and the latter for dispersed strata and very small areas.

Several types of analyses have been used to identify interrelationships between variables, some of which are discussed Marriott and Wint (1985). These are:

1. <u>The comparison of distribution maps,</u> which permits both visual assessments of the degree to which populations are aggregated, and also serves to suggest possible causes for such clustering.

2. The estimation of populations within various strata, which provides a rapid way of isolating characteristics of the survey area which may be associated with high livestock densities. The strata examined include ecological and geological land systems, drainage baisins, vegetation type and density, topographic dissection, altitude, administrative area, cultivation levels, distance to features such as towns, wells, roads and rivers, and so on.

3. Linear and multiple stepwise regression, using the values of selected parameters as recorded for each grid cell. These techniques quantify the relationships between the dependent and independent variables and in terms of slope and intercept, so that predictive relationships can be assembled. Pricipal components and trend surface analyses have also been used in a few cases, which again use individual grid values, but identify new axes made up from a combination of the raw variables, against which the parameter of interest can be plotted. In recent years, the use of individual grid values within such calculations has been questioned because it was thought that they did not represent truly independent samples. Thus, these techniques have not been used in the recent surveys. However, Marriott and Wint (1985) argue that the individual grid records can indeed by treated as independent samples, and so it is planned to reanalyse much of the recent data in due course.

4. The calculation of indeces, combining several parameters into a single value, such as a vegetation density index, or land suitability index (RIM ???). The major advantage of such indeces is that they may be linearly related to variation in the dependent variables, when the component parameters are not. However, these too are built up from individual grid values, and so, to date, they have only been analysed via regression techniques by calculating mean values for spatial strata, and using those as independent samples.

2.2.2 Presentation of Data.

The aerial survey data have been presented in two basic forms: tabular and graphic. The former is designed to provide rapid access to actual figures, largely for reference purposes. The latter has largely concentrated upon the provision of distribution maps, both as a tool to identify population foci, and as an initial step in the identification of relationships between animal or human populations, and selected environmental variables. Initially, such maps were produced by hand, but since 1983, a method of computer generation has been employed, which takes its data directly from the rectangular dataset. Relative population densities are then represented by proportional symbols.

2.2.3 Software Development.

It will be evident to those with experience of large scale data manipulation that the analytical steps described above are often lengthy and tedious. This is espececially true if each stage - bias corrections, data entry, data validation, data analysis and data presentation - involves the use of several different hardware and software systems.

In order to streamline the entire process, an integrated data entry, analysis and mapping software package has been developed for use on the HP150 microcomputer, equipped with a 16 Megabyte hard disk, and linked to a six pen flatbed graphics plotter and wide carrage printer (RIM, 1985). Data entry is by means of a suite of menu driven dBaseII programmes, with options for determining observer bias, mean grid cell values for multiple data entries, data listing and validation. Population estimation, standard error determination and mapping procedures are performed by a scaled down version of Mapics software previously run on a VAX11 computer. This software is currently being tested.

Although the command driven language system of mini-Mapics provides considerable flexibility in data manipulation and presentation it has relatively limited powers of detailed statistical analysis. The availability of suitable statistical packages for the HP150 is currently being investigated, with a view to providing a facility for more complex bivariate and multivariate analyses.

As the HP150 is readily transportable, it is now possible to start data entry and validation as surveys are being flown, provided a suitable power supply is locally available, and to produce print ready distribution maps and population estimates, soon after the survey has been completed.

3. THE RESULTS OF THE AERIAL SURVEYS

The results of the low level aerial surveys described in Section 1.5 have been presented in considerable detail in the various ILCA/RIM reports prepared as the individual surveys were completed. These results embrace a wide range of variables, including animal numbers and distributions, human habitation levels, and selected environmental parameters. It is not the intention of this review to reiterate the detailed findings of these reports, but rather to provide a broad overview and comparison of regional results, and to use examples to illustrate the potential and actual value of the survey methodology.

Table 2 contains a summary of the more generally relevant quantitative data collected in the Arid, Semi-Arid, Sub-Humid and Highland Zones of West Africa, between 1979 and 1984. These figures represent the mean levels of the various parameters estimated within each survey area, or within amalgamations of the smaller areas covered, and as such conceal considerable spatial variation. This is particularly true of the larger survey areas such as Southern Gongola State in Nigeria, or the Gourma region of Mali. Some of the more striking distribution patterns are discussed in Section 3.1.5 below, but as a general rule, the fine spatial structure of the populations and environmental descriptors are not considered to be strictly relevant to this review. Such stratified information has been treated in some considerable depth in the individual reports.

The major site groupings that have been made for the present purposes are the ILCA Case Study Areas in Nigeria, the three Grazing Reserve sites on the southern edge of the Semi-Arid Zone of Nigeria, and the four sub-zones of the Mali Delta. The individual survey sites within these groupings are considered to be too small to be directly comparable to the larger regions covered, as the small scale variations would be given excessive emphasis if considered separately. Two exceptions have been made to this general approach - the high Nigerian Sub-Humid grasslands of Jos and Mambila. These sites are so different to their surrounding regions, both in terms of environmental and livestock production criteria, that including them within any larger units would markedly bias the overall pattern.

The figures in Table 2 have been abstracted from the published reports, but have been augmented to some degree by additional unpublished data. The evolution of survey techniques since the Aerial Survey Unit's inception means that fully comparable data are not available for all sites. For example, several of the earlier surveys did not measure the levels of arable farmer habitation, or estimated them as the number of compounds, rather than the number of dwellings which was used from 1983 onwards. This does not reflect an oversight during the earlier surveys, but rather the fact that the potential value of assessing a full range of livestock human and environmental parameters has become apparent only in recent years. Also the information required of those earlier surveys was, in retrospect, somewhat limited in view of the range of data that was potentially available. There are then, effectively gaps in the data available, though the range of figures are still more than sufficient to provide a valid overview of the aerial survey results on a zonal basis.

Two further points should be considered when examining this information. The first is with respect to small ruminant counts. Experience has shown that a significant proportion of these animals are not visible from the air, in particular those kept close to, or even inside, human habitation or those herded in areas of dense vegetation cover such as southern Gongola. Recent reports (RIM ???) have argued that the sheep and goats that are amenable to

TABLE 2a
SUMMARY OF LOW LEVEL SYSTEMATIC RECONNAISSANCE FLIGHTS CARRIED OUT IN WEST AFRICA BY THE INTERNATIONAL LIVESTOCK CENTRE FOR AFRICA AND RESOURCE INVENTORY AND MANAGEMENT: 1979 -1984.

Country	Location	Area sq.km.	Date	Season	Height feet	Sample %	Report Reference	CATTLE Density	CATTLE StR	CATTLE MGS	SHEEP & GOATS Density	SHEEP & GOATS StR	SHEEP & GOATS MGS	CAMELS Density	CAMELS StR	CAMELS MGS	DONKEYS Density	DONKEYS StR	DONKEYS MGS	TLU Density	TLU StR
MALI																					
1	Inland Delta	35.844	10/80	Early dry				22.5 [8]	4.5	117	7.1(14)	14.0	79							16.5	6.1
		35.844	3/81	Late dry	800	8.5		33.8 [8]	3.0	98	12.7(15)	7.9	66	none referred to			none referred to			24.9	4.0
		35.844	6/81	Start wet				22.5 [8]	4.5	69	16.0(23)	6.2	108							17.4	5.7
	Tamascheq	1.324	2/82	Mid dry				2.4(43)	42.2	46	6.5(45)	15.3	73							2.3	43.5
			4/82	Late dry				0.3(61)	0.3	21	1.1(54)	90.1	43	none referred to			none referred to			0.3	333.3
			10/82	Early dry				36.6(25)	36.6	175	21.8(17)	4.6	84							27.8	3.6
	Cooki Nyaaso	1.161	2/82	Mid dry				20.1(40)	5.0	108	23.5(20)	4.3	123							16.4	6.1
			4/82	Late dry				41.5(15)	2.4	116	17.8(39)	5.6	67	none referred to			none referred to			30.8	3.2
			10/82	Early dry				5.5(71)	18.1	126	0	-	-							3.9	25.6
					800	17															
	Jallube Jenneri	960	2/82	Mid dry				39.2(12)	2.5	86	23.5(32)	4.3	113							29.8	3.4
			4/82	Late dry				53.8(11)	1.9	103	35.9(18)	2.8	125	none referred to			none referred to			41.3	2.4
			10/82	Early dry				7.3(24)	13.7	124	3.5(37)	28.3	107								
								5.5	18.2												
	Yongari Mangari	1.248	2/82	Mid dry																	
			4/82	Late dry				65.7(18)	1.5	89	6.0(24)	16.8	49							46.6	2.1
			10/82	Early dry				28.1(12)	3.6	54	10.2(25)	9.8	39	none referred to			none referred to			20.7	4.8
								7.3(49)	7.3	159	2.2(49)	45.7	68							5.3	18.9
2	Gourma	82.612	1/83	Mid dry	803	4.5		4.8(13)	20.7	36	7.1 (9)	14.2	51	<0.1	>1000	3	<0.1	>1000	7	4.2	23.8
		83.300	3/83	Late dry	803	9.1		4.3 [7]	23.4	46	7.0 (7)	14.3	71	<0.1	>1000	3	<0.1	>1000	7	3.8	36.4
		81.300	8/84	Mid wet	811	9.0		5.7 [7]	17.6	46	14.0(10)	7.1	95	0.1	939	4	<0.1	>1000	6	5.6 (6)	17.9
3	Office du Niger	6.500	5/83	Late dry	804	8-16															
	(Niono)	6.500	9/84	Late wet		8-16		11.8(41)	8.5	66	20.7	4.8	119	<0.1	>100	9	<0.1	>1000	4	10.4	9.6
								19.6(35)	5.1	83	18.6	5.4	113	0			<0.1	>1000	3	15.6	6.4

NB Standard Errors in brackets - Marriott SE's [thus] and Jolly SE's (thus)
Marriott SE's calculated where available
Total TLU figures include arable farmers goats, and similar proportions assumed for remaining sites within Sub-Humid Zone.
MGS = Mean group size, discussed in the text as Grazing Unit (GU) Size
StR = Stocking rate as hectares per head

TABLE 2b
SUMMARY OF LOW LEVEL SYSTEMATIC RECONNAISSANCE FLIGHTS CARRIED OUT IN WEST AFRICA BY THE
INTERNATIONAL LIVESTOCK CENTRE FOR AFRICA AND RESOURCE INVENTORY AND MANAGEMENT: 1979 -1984.

Country	Location	Area sq.km.	Date	Season	Height feet	Sample %	Report Reference	CATTLE Density	CATTLE StR	CATTLE MGS	SHEEP & GOATS Density	SHEEP & GOATS StR	SHEEP & GOATS MGS	CAMELS Density	CAMELS StR	CAMELS MGS	DONKEYS Density	DONKEYS StR	DONKEYS MGS	TLU Density	TLU StR
NIGER																					
	NRL Past. Zone	81.555	5/81	Late dry	843	9.2		3.5 [6]	28.2	33	9.6 (8)	10.4	46	0.9 (9)	116	5	0.2(14)	588	7	4.4	22.8
		81.555	10/81	Early dry	818	8.9		4.6 [6]	21.6	38	14.1(11)	7.1	70	1.1 (8)	91	6	0.2(11)	400	6	5.8	17.1
		81.555	9/82	Late wet	810	8.8		4.1 [8]	24.6	42	10.2 (8)	9.8	77	1.9(32)	52	20	0.3(12)	349	11	5.9	16.9
		81.555	9/85	Late wet				Results to be included when available.													
	Tchin Tabaraden	7.423	?/82	Dry	819	18.2		4.8(21)	20.6	34	8.1(14)	12.4	34	0.8(18)	123	4	0.2(14)	470	4	5.1	19.5
		7.423	?/82	Wet	810	18.0		6.9(10)	14.5	43	15.2(11)	6.6	69	0.5(31)	193	11	0.2(22)	594	5	6.9	14.4

NB Standard Errors in brackets - Marriott SE's [thus] and Jolly SE's (thus)
Marriott SE's calculated where available
Total TLU figures include arable farmers goats, and similar proportions assumed for remaining sites within Sub-Humid Zone.
MGS = Mean group size, discussed in the text as Grazing Unit (GU) Size
StR = Stocking rate as hectares per head

TABLE 2c
SUMMARY OF LOW LEVEL SYSTEMATIC RECONNAISSANCE FLIGHTS CARRIED OUT IN WEST AFRICA BY THE INTERNATIONAL LIVESTOCK CENTRE FOR AFRICA AND RESOURCE INVENTORY AND MANAGEMENT: 1979 -1984.

Country	Location	Area sq.km.	Date	Season	Height feet	Sample %	Report Reference	CATTLE Density	CATTLE StR	CATTLE MGS	SHEEP & GOATS Density	SHEEP & GOATS StR	SHEEP & GOATS MGS	CAMELS Density	CAMELS StR	CAMELS MGS	DONKEYS Density	DONKEYS StR	DONKEYS MGS	TLU Density	TLU StR
NIGERIA																					
1	Kirmin Biri	2,500	2/79	Late dry	1,000	20.0		17.3 (9)	5.8	51										15.1	8.3
			7/79	Mid wet	1,000	20.0		4.2(26)	23.8	54										3.7	27.0
			3/84	Late dry	1,000	14.7		7.9[17]	12.6	37	0.6	170.0	16							6.9	14.5
			9/84	Late wet	800	17.2		9.9[23]	10.1	58	0.9	118.0	13							8.7	11.5
2	Abet	2,475	2/79	Late dry	1,000	20.0		37.4 (8)	2.7	48										32.7	3.1
			7/79	Mid wet	1,000	20.0		22.7 (6)	4.4	61										19.9	5.0
			3/84	Late dry	1,000	14.7		32.8[12]	3.1	48	2.3	43.0	15							28.7	3.5
			9/84	Late wet	1,000	17.2		31.8[10]	3.1	52	2.8	36.0	18							27.8	3.6
3	Mariga	2,750	2/79	Late dry	1,000	20.0		6.6(16)	15.2	25										5.8	17.2
			7/79	Mid wet	1,000	20.0		23.5 (8)	4.3	53										20.6	4.9
			3/84	Late dry	1,000	14.7		9.4[14]	10.7	27	2.2	45.7	13							8.2	12.2
			10/84	Late wet	800	17.2		22.0[11]	4.5	46	3.5	28.9	16							19.3	5.2
4	Lafia SE	3,500	3/79	Late dry	1,000	20.0		12.7(19)	9.9	59										11.1	9.0
			7/79	Mid wet	1,000	20.0		37.7(14)	2.7	86										33.0	3.0
5	Jos Plateau	8,600	4/80	Late dry	1,000	20.0		16.4(11)	6.1	49										12.8	7.8
			9/80	Late wet	1,000	20.0		46.8(13)	2.1	70										36.4	2.7
	Sub-humid Zone	356,510	3/82	Late dry	1,000	1.4		10.3(11)	9.8	55										9.0	11.1
			7/82	Late wet	1,000	1.3		9.4(16)	10.6	68										8.2	12.2
6	Lafia NE	2,325	4/82	Late dry	800	16.0		16.4(17)	6.1	75										14.4	6.9
			10/84	Late wet	800	17.2		22.9[15]	4.4	70										20.3	4.9
7	Bauchi State	65,675	8/83	Mid wet	2,000	16.0		Livestock not recorded.													
8	Azare	4,250	8/83	Mid wet	500	4.0		Livestock not recorded.													
9	Gongola State	43,875	7/83	Mid wet	700	14.2		15.7 [4]	6.4	43	1.3 (9)*	76.8*									
			2-3/84	Mid dry	700	10.3		13.6 [5]	7.4	41	1.5(13)*	66.2*									
10	Sorau	1,325	8/83	Mid wet	700	14.2		11.2[21]	8.9		3.7*	27.0*									
			3/84	Late dry	700	10.3		5.7[20]	17.5		7.0*	14.3*									
11	Garkida	1,600	8/83	Mid wet	700	14.2		12.0[21]	8.3		2.8*	35.7*									
			3/84	Late dry	700	10.3		5.4[13]	18.5		3.4*	29.4*									
12	Wawa Zangi	3,750	8/83	Mid wet	700	14.2		10.6[12]	9.4		1.8*	55.6*									
			3/84	Late dry	700	10.3		7.2 [9]	13.9		5.5*	18.2*									

NB Standard Errors in brackets - Marriott SE's [thus] and Jolly SE's (thus)
Marriott SE's calculated where available
Total TLU figures include arable farmers goats, and similar proportions assumed for remaining sites within Sub-Humid Zone.
MGS = Mean group size, discussed in the text as Grazing Unit (GU) Size
StR = Stocking rate as hectares per head

* Pastoral sheep only - excludes arable goats.

TABLE 2d

SUMMARY OF LOW LEVEL SYSTEMATIC RECONNAISSANCE FLIGHTS CARRIED OUT IN WEST AFRICA BY THE INTERNATIONAL LIVESTOCK CENTRE FOR AFRICA AND RESOURCE INVENTORY AND MANAGEMENT: 1979 -1984.

Country	Location	Area sq.km.	Date	Season	Height feet	Sample %	Report Reference	CATTLE			SHEEP & GOATS			CAMELS			DONKEYS			TLU	
								Density	StR	MGS	Density	StR	MGS	Density	StR	MGS	Density	StR	MGS	Density	StR
NIGERIA																					
13	Pambegwa	3,000	3/84	Late dry	1,000	7.4		18.2[14]	5.5	42	2.3	43.2	22								
			10/84	Late wet	800	8.6		16.6[12]	6.0	38	3.7	27.2	22								
14	Funa Funa	750	4/84	Late dry	1,000	14.7		2.9[45]	34.5	31	1.6	61.6	14								
			10/84	Late wet	800	17.2		3.8[16]	26.4	31	0.9	106.0	14								
15	Ganauri	800	3/84	Late dry	1,000	14.7		24.3[14]	4.4	34	1.3	75.8	13								
			9/84	Late wet	800	17.2		29.1 [7]	3.4	36	5.0	20.0	22								
16	Tegina-Minna	3,250	3/84	Late dry	700	5.1		19.4[20]	5.1	47	3.2	31.3	17								
			10/84	Late wet	800	8.6		20.1[15]	5.0	37	2.5	39.7	17								
17	West Zaria	3,350	4/84	Late dry	700	10.3		24.4 [9]	4.1	32	3.5	28.6	12								
			10/84	Late wet	800	8.6		31.4 [8]	3.2	50	2.8	36.0	15								

NB Standard Errors in brackets - Marriott SE's [thus] and Jolly SE's (thus)
Marriott SE's calculated where available
Total TLU figures include arable farmers goats, and similar proportions assumed for remaining sites within Sub-Humid Zone.
MGS = Mean group size, discussed in the text as Grazing Unit (GU) Size
StR = Stocking rate as hectares per head

estimation from the air are predominantly those owned by pastoralists, and so are herded in association with cattle. This suggests that in the more northern parts of West Africa, where the vegetation canopy is comparatively open, and arable farmer populations relatively sparse, the estimates of total sheep and goat numbers "shoats" are likley to be reliable. In contrast, in the more southerly (Sub-Humid) Zone, "shoat" numbers will have been substantially underestimated. It should be realised, however, that even if the sheep and goat populations in the Sub-Humid Zone have been undercounted, the degree of under counting should be consistent, and so the relative distribution patterns obtained will be reliable, as will the relative abundances of different animal catgories.

A problem, however, undoubtedly remains when comparing "shoat" densities in different ecological zones, or in widely disparate survey areas. This problem was addressed in southern Gongola State, where the absolute errors were likely to be largest, by estimating the numbers of small ruminants which did not belong to the pastoralists during ground based surveys (RIM ???). Estimates of numbers per arable farmer compound were obtained by interview, in a representative series of localities throughout the survey area. As the number of arable farmer dwellings within each grid cell were estimated from the air, it was possible to calculate the number of compounds per grid that these dwellings represented, making only a single assumption of the mean number of huts per compound. These figures were then applied to the estimates of "shoat" numbers per compound, thus providing both abundance and distribution data.

The second point to be considered concerns the standard errors of the population totals presented in Table 2. As discussed in Section 2.2.1, a new method of calculating these error estimates has recently been developed (Marriott and Wint, 1985) which is less sensitive to the patchiness of a population than the methods previously available. Where possible, therefore, the survey data has been completely re-analysed, and the errors quoted derived from the Marriott technique. There are, however, some survey zones from which the raw data has not been available to the authors and so the errors quoted remain those derived from the old technique.

3.1 THE ANIMAL POPULATIONS

3.1.1 The Species Recorded by Aerial Survey.

The domestic animals raised by livestock-producers in the aerial survey zones are camels, cows, goats, sheep, pigs, horses and donkeys. Cows, camels, equines and small ruminants associated with pastoral herds can be counted from the air, and the major subtypes of cattle in some regions can be distinguished by coat colour. Overall sheep, goat and pig numbers can only be assessed by indirect methods. Equines can be counted, but are usually present in such small numbers that this was not attempted. The following table shows the presence or absence of particular species observed in the zones surveyed.

Table 3. The animal species recorded by aerial surveys.

Region	Cows	Camels	Sheep	Goats	Pigs	Horses	Donkeys
Delta	+	-	+	+	-	+	+
Gourma	+	+	+	+	-	+	+
NRL	+	+	+	+	-	+	+
SHZ.Nigeria	+	-	+	+	+	+	+
Gongola	+	-	+	+	-	+	+

3.1.2 Overall Animal Numbers and Grazing Unit Sizes.

All the densities described in the following sections are summarisied in Table 4, and are, unless otherwise stated, taken from the most recent set of surveys of the sites in question. Thus, for example, though the ILC Case Study Areas in Nigeria were flown in both 1979 and 1984, only the 1984 figures have been abstracted to give mean population levels. If however a specific site was covered several times in a single season, as were the parts of the Mali Delta, then these values have been combined to provide a single population figure for each season. If this had not been done, then the resulting descriptions would have been as long as the original reports.

3.1.2.1 Cattle

The statistical significance of the differences between the values for cattle densities presented are summarized in Table 5, and are calculated according to the methods described in section 2.2. Any contrasts described within the text are significantly different at at least the 5% level unless otherwise stated.

It should also be mentioned that calculations of statistical significance for difference in densities have only been performed for the cattle figures, because extensive reanalysis of the existing data would be required to produce the necessary estimates of standard errors, and there han not been enough time to reorganise and reanalyse the TLU, camel, small ruminant and human population records. However, it seems reasonable to assume that statistical proof of the quoted differences in these other parameters can safely be assumed.

3.1.2.1.1 Annual mean densities within the ecological Zones.

The total mean cattle densities encountered between 1979 and 1984 range from 3.5 to 60 per square kilometer in the NRL area and the Mambila Highlands respectively. This range conceals values of as low as 0.3 in L'Unite Tamasheq in the north of the Mali Delta, and as high as 79.5 in the southern part of the Mambila Plateau.

An indication of the year round cattle densities supported by the various localities on a zonal basis can be gleaned by examining the meaned wet and dry season figures for each area. The Arid Zone sites - NRL (including Tchin Tabaradene) in Niger and the Gourma in Mali - carry the lowest cattle densities at some 4.6 per square kilometer (21.7 hectares per head). The Semi Arid regions support approximately four times as many cattle as does the Arid Zone:

TABLE 4 THE ANNUAL AND SEASONAL MEANS FOR LIVESTOCK DENSITIES RECORDED FROM AERIAL SURVEY (Figures are numbers per square kilometer)

SITE, REGION	DRY SEASON				WET SEASON				ANNUAL			
	TLU	Catt	Cam	Sho	TLU	Catt	Cam	Sho	TLU	Catt	Cam	Sho
ARID ZONE												
Niger RL	5.16	4.05	1.0	11.8	5.93	4.1	1.9	10.2	5.55	4.08	1.45	10.0
Gourma	4.69	4.55	0.8	7.05	5.89	5.7	0.5	14.0	5.29	5.13	0.65	10.5
Total	4.90	4.29	0.9	9.43	5.92	4.9	1.2	12.1	5.41	4.6	1.05	10.3
SEMI ARID ZONE												
Delta	20.7	28.2	+	9.9	16.1	22.5	+	16.0	18.4	25.3	+	13.0
Niono	10.3	11.8	+	20.7	15.6	19.6	+	18.6	13.0	15.7	+	19.7
NLPU Gr Res	5.06	6.47	0	5.3	8.0	11.0	0	2.4	6.51	8.76	0	3.85
Total	17.2	23.0	+	10.7	14.9	20.6	+	14.5	16.1	21.8	+	12.6
Total-Delta	7.7	9.1	+	12.9	11.7	15.3	+	10.4	9.69	12.2	+	11.6
SUB-HUMID ZONE												
Gongola low	7.8	11.0	(19.4)	1.15	6.93	9.73	(19.4)	1.1	7.4	10.4	(19.4)	1.1
Case Areas	13.0	18.3		2.37	15.5	21.8		2.7	14.3	20.1		2.6
All lowlands	9.68	13.6	(19.4)	1.55	9.97	14.0	(19.4)	1.7	9.82	13.8	(19.4)	1.6
HIGHLANDS	16.4	22.8	(18.7)	4.3	36.4	51.7	(18.7)	2.6	26.4	37.3	(19.4)	3.4
TOTAL in SHZ	10.9	15.3	(19.3)	1.8	14.8	21.1	(19.3)	1.8	12.9	18.2	(19.3)	1.8

N.B. Values in parentheses in the camel column represent arable farmers' goats as counted from the ground. TLU values do not include these goats, to facilitate comparisons with figures from the Arid and Semi-Arid Zones.

TABLE 5 SUMMARY OF STATISTICAL SIGNIFICANCE OF DIFFERENCES BETWEEN AERIAL SURVEY ESTIMATES OF CATTLE DENSITIES PER SQUARE KILOMETER.

REGIONS		ARID	S/A ALL	SHZ ALL	S/A - DELTA	SHZ LOW	DELTA	HIGHLANDS
Significance of interzonal differences								
ARID			001 15.67	001 52.42	001 3.62	001 12.90	-	-
S/A ALL	W	001		02				
	D	001		2.73				
SHZ ALL	W	001	NS					
	D	001	001					
S/A-DELTA	W	001				NS	001	001
	D	001				0.73	5.39	7.59
SHZ LOW	W	001			NS		001	001
	D	001			10		7.99	8.84
DELTA	D	001			10	001		001
	W	001			001	001		4.19
HIGH-LAND	D	001			001	001	001	
	W	001			001	001	02	
Significance of intrazonal seasonal differences								
WET/DRY		02 2.50	NS 1.15	001 3.86	NS 1.48	NS 0.31	02 2.33	001 9.02

Significance level and Z value for difference between annual means
Z is significant at 5% if above 1.96

Significance level of differences between Zones in wet and dry seasons

NB Whilst all of the possible comparisons have been perfomed, only the most relevant ones have been presented in the above in order to simplify its presentation.

a yearly average of 21.8 cattle per square kilometer, equivalent to a stocking rate of 4.6 hectares per head. The equivalent figure for the Sub-Humid Zone is somewhat, but significantly ($p < 0.02$) lower at 18.2 cattle per square kilometer or 5.5 hectares per head.

These average figures for the two southerly Zones are, however, misleading as they each include exceptional areas - the Mali Delta in the Semi-Arid Zone, and the High Grasslands of Jos and Mambila within the Sub-Humid Zone - both of which are relatively better watered than the surrounding land. If these areas are excluded, so as to obtain a figure which is likely to more truly represent cattle densities on average rangeland in each zone, the Arid, Semi-Arid and Sub-Humid Zones support 4.6, 12.2 and 13.8 cattle per square kilometer respectively, the last two figures being statistically indistinguishable; the Mali Delta 25.3 cattle per square kilometer; and the High Grasslands, higher again ($p<0.001$), at 37.3 cattle per square kilometer.

Thus, the aerial survey results show that, average year round cattle density decreases from south to north, as might be expected, with the Arid Zone pastures supporting approximately a third the densities found in the two ecozones to the south. The Semi-Arid and Sub-Humid Zones are, however, rather similar: both carry cattle populations of 12-13 per square kilometer; and both contain areas which hold an average of between two and three times the densities found on the grazing land more representative of the Zones as a whole.

3.1.2.1.2 Zonal population estimates.

If it is assumed that these figures are representative of the ecological Zones as a whole, and that a particular Zone varies little with country, then these estimates can be extrapolated to give average densites within each Zone. For Mali, these can then be compared to the densities quoted in the published literature.

These extrapolated estimates for Mali are much higher than the published figures (Table 6). This is particularly true for the Arid Zone, where the extrapolated population is no less than 4.2 times the estimate quoted in ILCA (1981). This extraordinary discrepancy may derive from the assumption that the entire Zone is populated at a similar density to that found in the Niger Pastoral Zone or the Gourma Region, which may be invalid. It could also be due to a substantial overestimate by aerial survey, an equivalent underestimate by the other methods described in ILCA (1981), or inaccuracies in both estimates.

As far as the other zones are concerned however, the discrepancies between aerial survey extrapolation and published information are less extreme, though still considerable. Thus the air-derived densities are 1.6-1.7 times the ILCA (1981) for the non refuge pastures (i.e excluding the delta and high grasslands from the aerial calculations). This rises to a factor of 2.1 if the Delta is included within the Semi-Arid Zone figures.

Thus aerial survey would suggest that cattle densities in Mali are as much as double the previous estimates. Aerial survey techniques are likely, if anything, to underestimate livestock populations, because some animals are obscured from the air. It therefore seems very likely that the published figures are indeed considerable underestimates of the actual cattle populations.

A possible explanation for this phenomenon is that animals in the more remote

TABLE 6 COMPARISON OF LIVESTOCK POPULATION ESTIMATES FROM VARIOUS SOURCES

SOURCE	COUNTRY	ANIMAL	ZONE OR REGION ARID	SEMI ARID	S/A+DELTA	SUB-HUMID	SH+HIGHLANDS	
A. DENSITIES PER SQUARE KILOMETER								
ILCA (1981)	Mali	Cattle	1.1	7.69	10.2	7.8		
		Shoats	4.2	12.7	15.4	6.1		
JAHNKE (1982)	Mali	Cattle	2.6	6.7		1.8		
		Shoats	9.8	11.1		0		
AERIAL SURVEY	Zone	Cattle*	4.6	12.2	21.8	13.3	17.4	
		@Shoats*	10.3	11.6	12.6	1.6	1.8	
		&Shoats*				21.1	21.0	
B. ESTIMATED TOTAL POPULATIONS (MILLION)								
ILCA (1981)	Mali	Cattle	0.94	1.47	2.58	1.01		=6
JAHNKE	Niger	Cattle	2.45	0.55		0		
	Mali	""	2.23	2.14		0.09		4.5
	Nigeria	""	0.24	8.70		1.80		
AERIAL SURVEY	Niger	Cattle	5.54	0.76	1.35	0		
	Mali	""	3.90	3.91	6.99	0.68	0.89	—17.
	Nigeria**	""	0.07	3.94	7.04	5.47	7.02	

NB Areas for Aerial Survey extrapolations taken from Jahnke (1982)
Densities of Aerial Survey estimates for Semi-Arid+Delta and SHZ+Highlands are means and NOT additions.

* Annual means
@ Excluding Arable farmer goats
& Including arable farmer goats
** High intensity surveys

areas are not reliably assessed on the ground. This may explain why the discrepancy between the two sets of figures is greatest for the Arid Zone, of which a large part is extremely remote. A further source of possible undercounting by ground based methods is that many pastoralists are liable to conceal some of their animals where they are taxed.

However, the accuracy of the aerial survey extrapolations does depend in large part on the assumption that the areas surveyed are truly representative of the Zones as a whole. The validity of this assumption can be examined by comparing the figures for the Sub-Humid Zone of Nigeria as derived from high intensity surveys similar to those performed in the Arid and Semi-Arid Zones, with those derived from a very low intensity, but zone-wide survey. The low intensity survey suggests a yearly mean cattle population density of 9.8 per square kilometer, in comparison to a figure of 13.3 per square kilometer derived from the high intensity survey. Though it is possible that this discrepancy between the two estimates is due to an inherent inaccuracy of the methods involved, it is more likely that the difference derives from three other factors. Firstly, the high intensity surveys were conducted in areas which were known to contain substantial cattle populations, and thus the estimates derived from them do not take into account regions which are relatively devoid of cattle, such as the south-western quadrant around Ilorin. Secondly, the high intensity figures are likely to be biased upwards to some extent by the fact that many pastoralists remained in the Sub-Humid Zone during the wet season of 1983 in an attempt to avoid both the rinderpest epidemic and the drought to the north. Thirdly, the low intensity survey was flown two years before the high intensity one. If the northern droughts did, indeed, lead to a significant influx of cattle into the SHZ, then a 35% increase over two years is conceivable.

If these caveats are feasible, then the ILCA (1981) estimates for the Malian cattle populations are, indeed, much too low. Even if these possible sources of bias do not operate, it remains likely that these ILCA estimates of very considerable underestimates, by a factor of at least 60%.

A further comparison can be made with the FAO figures presented in Jahnke (1982) for the 1979 cattle populations and land areas of the various Zones in Mali, Niger and Nigeria (Table 6). This comparison shows also that aerial survey estimates are generally considerably higher than Jankhe's figures, particularly in Mali and Niger. In Nigeria, however, aerial survey estimates rather lower National cattle population than does Jankhe (if the HIghlands are excluded), and further suggests a radically different distribution of animals within that country, with many more cattle in the Sub-Humid Zone and markedly less in the Semi-Arid Zone. This may reflect a southward dispersal of cattle into the Sub-Humid Zone, or may be due to the fact that the aerial survey Semi-Arid figures derive largely from Mali, rather than Nigeria which may indeed be more heavily stocked.

3.1.2.1.3 The potential for expansion.

De Leeuw's estimates for carrying capacity in relation to rainfall (in Putt et al, 1980) imply a potential density of 13, 20 and 40 TLU per sqaure kilometer in the Arid, Semi-Arid and Sub-Humid Zones respectively. Thus, the figures discussed in the preceding paragraphs suggest that, with the notable exceptions of the Mali Delta during the dry season, and much of the Highland areas within Sub-Humid Zone throughout the year, the cattle populations supported by all the sites surveyed are comparatively lightly stocked, even despite the fact that aerial survey estimates are generally much higher than those previously published.

This implies that there is considerable room for expanding the livestock populations in the future. In the Arid and Semi-Arid Zones they could at first sight be doubled, and tripled times in the Sub-Humid Zone, with a commensurate increase in yield, in terms of both meat and dairy products.

Such assertions must, however, be treated with extreme caution. Firstly, the extensive range degradation reported within all Zones suggests that much of the land is already overstocked at some period during the year. Also, given the principle of limiting factors, livestock populations may be limited in some years but not others as a result of, for example, drought. The resultant overgrazing may lead to rangeland deterioration which may last for several years, unless allowed to recover. Therefore, unless livestock densities can be assumed to respond immediately to current conditions, via mortality or migration, carrying capacities should, ideally, be calculated for the worst conditions.

Thirdly, much of the land surveyed is unavailable to pastoralists and their cattle. In the Mali Delta, for example, considerable areas are inundated until quite late in the dry season, and a further significant proportion is cultivated. Thus, according to de Leeuw and Milligan in ILCA (1981), only half the Delta is actually available for grazing during the wet season. Similarly in the Gourma, a wide band of land to the south of the Niger river is devoid of water even in the wet season. Thus effective cattle densities may be substantially higher than is initially apparent, and so the potential for livestock expansion consequently decreased.

The amount of land which cattle can actually graze is difficult to ascertain, particularly as the constraints on land use will vary with season. It has not yet proved possible to reanalyse the data from the earlier aerial surveys in sufficient depth to calculate the proportion of land suitable for cattle, and so estimate the effective cattle densities.

It has, however, proved possible to make such estimates from the southern Gongola dataset, largely because many of the more obvious seasonal constraints on cattle grazing, such as availability of dry season water and grazing land, do not operate in this region. This makes the identification of land which is permanently unsuitable for cattle rearing comparatively simple. The major factors which render land unsuitable in this area are a mountainous nature, dense vegetation cover, the presence of tsetse, and competition for land from arable farming, urban expansion, and finally forest and game reserves.

If these characteristics are taken into account, then a total of 32% of southern Gongola State can be assumed to be unsuitable for cattle rearing. Even this may be an underestimate, as percentage cultivation was not included in the calculations, and nor was pasture erosion, the former on the grounds that cropping levels need to be very high to exclude cattle altogether, and the latter because its incorporation would have brought much of the Mambila Plateau into the unsuitable category. Further, tsetse fly distribution was also ignored as the most recent information on its distribution suggested that <u>Glossina morsitans</u> is largely limited to the Gashaka Game Reserve from which cattle are excluded, and the distribution of the remaining tsetse species is insufficiently documented.

Thus the effective cattle densities in the southern Gongola survey zone are likely to be 20-23 per square kilometer, as opposed to the figures of 14-16 per square kilometer suggested by the uncorrected survey estimates. If the year round carrying capacity of the Sub-Humid Zone is taken as 2-3 hectares per head, as can be inferred from de Leeuw's estimates in Putt et al (1980), then this figure would only allow for a 50-100% rise in the present population of the region, rather than the 2-3 fold increase initially suggested by the estimated cattle population levels.

In areas other than Gongola, water, pasture quality and intense cultivation are likely to replace land dissection and vegetation density as causes of unsuitability. If, as a result, a similar proportion of land is unsuited to cattle in the Semi Arid and Arid Zones, then the maximum potential increase in livestock densities is as little as 40-60%, assuming that all livestock are cattle. As in these Zones, other livestock form a substantial proportion of the total TLU levels (see section 3.1.4 below) then it is arguable whether there is any room for an increase of any sort. This in turn suggests that the most desirable means to increase the levels of offtake in these drier areas is to raise turnover rates rather then numbers.

3.1.2.1.4 Variation in annual mean cattle densities within Zones.

Within two of the ecological Zones, the Arid and Sub-Humid, a sufficiently large number of surveys have been conducted to enable some broad conclusions to be drawn concerning intra-zonal variations in cattle population levels.

Of the Arid Zone sites, the Gourma supports 25% higher cattle densities than the Niger Pastoral Zone ($p<0.001$). However, when expressed in absolute terms, this difference is small in comparison to the variation between Zones.

Of the Sub-Humid Zone areas, two large scale groupings are possible: the highlands and lowlands, as has already been discussed in the preceding paragraphs; and the eastern and central sites (RIM ???). The survey zones in the 'central corridor' of the Nigerian Sub-Humid Zone - i.e the area defined by Milligan and Bourn (1983) and Milligan, Bourn and Wint (1984) as being associated with the major north/south commercial and historical axis of Nigeria - supports cattle densities some 1.5 times that of the eastern regions as represented by southern Gongola State.

This difference is not, however, consistent with altitude. The eastern highlands of Mambila hold some 50% more cattle per square kilometer than does the Jos Plateau, while the central lowlands support about twice the densities of cattle found in the lowlying areas to the east of the country.

3.1.2.1.5 Seasonal changes in cattle density.

The seasonal changes in Zonal cattle population densities, including the refuge areas of the Mali Delta and the Sub-Humid high grasslands, suggest that there is relatively little variability in either the Arid or Semi-Arid Zones, but that there is a significant ($p<0.001$) influx of cattle into the Sub-Humid Zone during the wet season. This runs contrary to the widely accepted view that the southerly pasture lands are avoided by pastoralists during the rains because of the unacceptable levels of tsetse challenge. The great majority of this increase is, however, due to a steep rise (225%) in the number of cattle to be found on the high grasslands during the wet season, many of which move out of Nigeria and into neighbouring Cameroun during the dry months, thus escaping the attentions of the Aerial Survey Unit.

Within the Zones, the survey sites can conveniently be grouped into three categories: those which showed little if any seasonal variation; those where dry season populations markedly exceeded those present in the wet season; and, in contrast, those where wet season populations were higher those of the dry season (See Figure 3).

To the first of these categories can be assigned two groups of survey areas. In the Arid Zone sites, the average wet and dry season densities varied little in absolute terms (4.9 and 4.3 per square kilometer respectively), though the wet season densities were the higher by some 14% ($p<0.02$). Cattle densities in the lowland Sub-Humid Zone sites did not vary significantly with season, the mean wet season density being 14.6 cattle per square kilometer, as opposed to a dry season equivalent of 13.6.

The second of these groups is effectively restricted to the Mali Delta, where, of course, large tracts of potential grazing are flooded during the late wet and early dry seasons, and are thus unavailable to pastoralists and their cattle (see section 3.1.2.3). Further, there is adequate wet season grazing in the areas outside the Delta, thus obviating the need to utilise what is effectively a dry season refuge. In this area, cattle densities were thus found to range from a low of 14.2 to 22.5 per square kilometer in the late wet and early dry season, to a high of 30 - 34 per square kilometer in mid and late dry season, which represents an seasonal increase of 110 - 150% ($p<0.02$).

The third category includes the non-Delta sites in the Semi Arid Zone, and the Nigerian Highlands. In the former, wet season cattle densities were estimated to be some 68% higher than those in the dry season, at 15.3 per square kilometer. These represent the widely available wet season pastures to where much of the pastoralist population disperse at the end of the dry season, before moving back to dry season grazing at the end of the rains. Table 5 shows that this seasonal variation is not statistically significant, due to the considerable variation in cattle densities between sites, as well as the fact that the areas covered were relatively small. Within each site, however, the seasonal variations were consistently significant at the 2% level, which suggests that the wet season increase is, indeed, a real phenomenon.

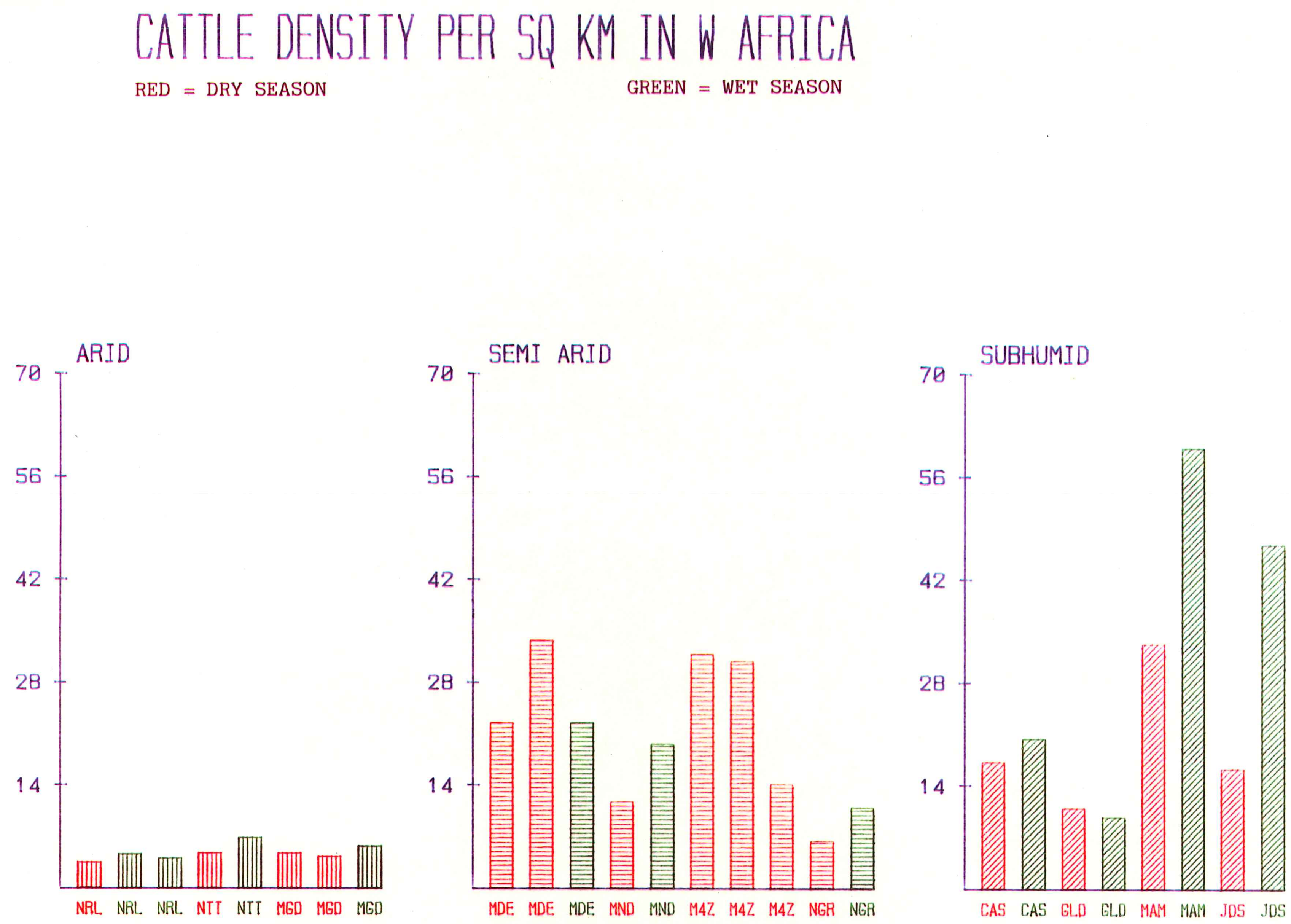
The Highlands of Nigeria also support wet season densities that are well in excess of (approximately twice) the dry season ones, at an average of some 51.7 cattle per square kilometer, which is equivalent to a stocking rate of 1.9 hectare per head. These sites, like the Delta Region of Mali, represent seasonal refuges, though in this case during the wet season, when the surrounding lowland grazing lands are made unsuitable by the reputedly high tsetse challenge which is associated with the comparatively dense vegetation cover.

3.1.2.1.6 Cattle Breeds.

As well as obtaining estimates of overall cattle densities, the technique of low level aerial survey makes it possible to differentiate between breeds or colour types of cattle in those instances where they are not herded in mixed groups. Two large scale surveys have made use of this possibility - NRL area of Niger and the Toungou Block region of southern Gongola State in Nigeria. In both, two colour types were easily distinguished from the air: white long horned Fulani (bunaji) and red Bororo (rahaji) in Gongola; and in Niger, the red Bororo and the dark red Azawak Zebu.

Examining the cattle colour types separately allows, for example, the seasonal changes in population density to be interpreted in greater detail. Thus in southern Gongola, it was evident that the relatively slight fall in total

FIGURE 3


CATTLE DENSITY PER SQ KM IN W AFRICA
RED = DRY SEASON
GREEN = WET SEASON
ARID
SEMI ARID
SUBHUMID
70
56
42
28
14
NRL
NRL
NRL
NTT
NTT
MGD
MGD
MGD
MDE
MDE
MDE
MND
MND
M4Z
M4Z
M4Z
NGR
NGR
CAS
CAS
GLD
GLD
MAM
MAM
JDS
JDS

cattle numbers from wet to dry season was, in fact largely attributable to a marked rinderpest-induced fall in the abundance of red cattle located in the Mambila hihglands, which was compensated for by a rise in the numbers of white cattle found the the lowland regions. Similarly, in Niger, the 27% increase in cattle densities recorded during the wet season was caused almost entirely by a rise in the number of Bororo.

3.1.2.1.7 Grazing Unit Size.

A variable closely akin to the overall population density estimates, that was also measured from the air, is grazing unit size. In previous ILCA/RIM reports, the terms 'herd and 'grazing unit' (GU) as observed from the air were treated as synonymous. However, it has become increasingly evident from ground studies conducted in the Nigerian Sub-Humid Zone, that it is preferable to treat GU's as management units, and contrast them with 'herds', that is the unit of ownership. Thus, GU's, as observed from the air, may be made up of several small herds, or alternatively, an owner of several hundred cattle may spilt his herd into several smaller Grazing Units.

Various factors can control GU size. The availability and skill of the labour involved, for example, will determine the number of cattle that can be effectively controlled at a point source such as a well or a bore hole, or in areas of intense cultivation, where trampling must be reduced to a minimum. Also, herds which have been split during the dry season into one group of lactating and weak adults together with the calves, and one group of animals to be sent on transhumance, will be assembled in different (usually smaller) GU's than during the wet season.

Recorded mean GU sizes in the Arid Zone vary comparatively little with either season or locality. Yearly means range from approximately 39-44, and seasonal means from 38-44. Similar figures were found from both highland and lowland Sub-Humid Zone sites, the yearly means were equivalent at 44.5, and seasonal means in the lowlands varying from 43-46. In the Highlands, however, the seasonal variation in GU size was more marked, being 51 in the wet season, and 36 in the dry season. This contrast with the lowland figures probably reflects two phenomena: dry season herd splitting as discussed above, more prevalent in the highlands because the cattle are sent long distances in the dry season when compared to many of the lowland cattle, which are frequently restricted to short distance movements; and the impact of rinderpest on the Mambila Plateau which may have reduced overall stocking levels by as much as 30% through mortality and disease induced sales.

The range of mean GU sizes in the Semi-Arid areas is considerable - from 25.3 in Semi-Arid Nigeria to 107.5 in the Mali Delta, both during the dry season. In general, the cattle outside the Delta are managed in smaller units (yearly mean = 48), than are those within the Delta (yearly mean = 78). Further, the seasonal variability is marked. In the Delta, wet season grazing units average 69 head, which is only 64% of that recorded in the dry season. The reverse is the case outside the Delta, where their mean sizes were estimated to be 54 in the wet season and 42 in the dry season.

3.1.2.2. Pastoralists' Sheep and Goats.

As discussed in the introductory paragraphs to section 3, only those sheep and goats owned by pastoralists, and herded with their cattle are amenable to aerial survey counts of the type employed in the ILCA/RIM surveys. It is therefore to these animals that the following section refers.

Within the two major Arid-Zone survey sites, which occupy 162,900 square kilometers, a yearly mean sheep population of some 1.67 million can be derived from the aerial counts. This suggests a density of approximately 10.3 animals per square kilometer, or 9.75 hectares per head. The equivalent figure for the Semi-Arid localities outside the Mali Delta is 11.64 per square kilometer, as compared with 12.6 within it. In the Sub-Humid Zone, estimated yearly mean sheep densities are less than a fifth of those in the two northern Zones, at 1.8 per square kilometer. The high grasslands of Mambila support about twice the sheep density of the surrounding lowland regions on a year round basis - some 3.4 as opposed to 1.6 animals per square kilometer.

There is thus a fairly clear geographical trend in the densities of small ruminants herded by pastoralists, which contrasts sharply with that found for cattle (see section 3.1.2.1.). A similar clarity is not evident with respect to seasonal variations in density. On a zonal basis, estimates of wet season sheep and goat density are some 30-35% higher than those of the dry season in the Arid and Semi-Arid Zones, and the two are essentially identical in the Sub-Humid Zone. Within the Zones, however, there is no such consistency. In the Gourma and Delta regions of Mali, wet season populations were the higher by a factor of 1.5 or 2. In the Mambila Highlands and Semi-Arid Grazing Reserve sites of Nigeria, the reverse was found to be the case, while in the remaining areas, little seasonal changes were detected.

As well as being less easy to fit into an overall pattern than the cattle data, there is little evidence from these figures that either the Mali Delta or the Sub-Humid high grasslands act as refuges for small ruminants in the way that they do for cattle. One implication of this is that the pastoralists who do move their stock into the refuge areas own comparatively few sheep.

From these estimates, it is possible to extrapolate to overall National population figures pastoralists' sheep and goats within each ecological Zone, which can then be compared to existing published figures (Table 6). Within Mali, the calculated sizes for the Arid, Semi-Arid, and Sub-Humid Zone small ruminant populations are 8.78 million, 2.22 million, and 208 thousand respectively. This compares with 3.6 million, 2.42 million and 790 thousand as presented in ILCA (1981). Thus, the major discrepancy is again in the Arid Zone estimates, and in this context it is interesting to note that Jahnke's estimate of shoat density in the Arid Zone is very similar to that derived from aerial survey (9.76 as opposed to 10.26 per square kilometer).

As expected, the Sub-Humid Zone estimates are much lower than the published figures because they are less easily be seen from the air and so supplementary census techniques are needed. Of particular concern, are.the sheep and goats owned by arable farmers. The relative importance of this category of animals can be seen from the population estimates of arable farmers' goats collected in Southern Gongola, using a combination of ground and air survey techniques (see above, and RIM ???). In this area, the overall population of goats was calculated to be some 846,000 or 19.3 per square kilometer. Thus the proportion of the total small ruminant population in southern Gongola that represents pastoralists' animals is, at most, 7%.

Translation of this proportion to the Sub-Humid Zone of Mali, would suggest that the total small ruminant population is 1.65 million, which is about twice the figure given in ILCA (1981). Some possible reasons for this disparity have been discussed in connection with cattle in the preceding section.

A point of some relevance in this regard in that aerial survey is well known to undersetimate small ruminant populations in all areas with trees or extensive human habitation. Thus it would seem likely that the sheep and goat populations outside the Sub-Humid Zone are markedly higher than suggested above, particularly in the Semi-Arid Zone, where no correction has been made for goats kept by arable farmers. Thus as with cattle, aerial survey suggests that the size of small ruminant populations at least in Mali, have hitherto been seriously underestimated.

3.1.2.3. Camels, Donkeys and Horses

Though camels were observed in several Semi-Arid locations, their estimated densities were negligible at 0.1 per square kilometer or less. None were observed in the Sub-Humid Zone areas. By contrast, significant numbers were recorded in both the Arid Zone regions averaging some 1.05 per square kilometer. The seasonal figures suggest that these animals leave the Gourma during the wet season, but leave the Niger Pastoral Zone during the dry season.

Equines were observed in all areas, but again in very small numbers when compared to the major livestock species. As with camels, the highest densities (0.2 - 0.3 per square kilometer) were recorded in the Arid Zone sites, and there was no evidence of any seasonal variation.

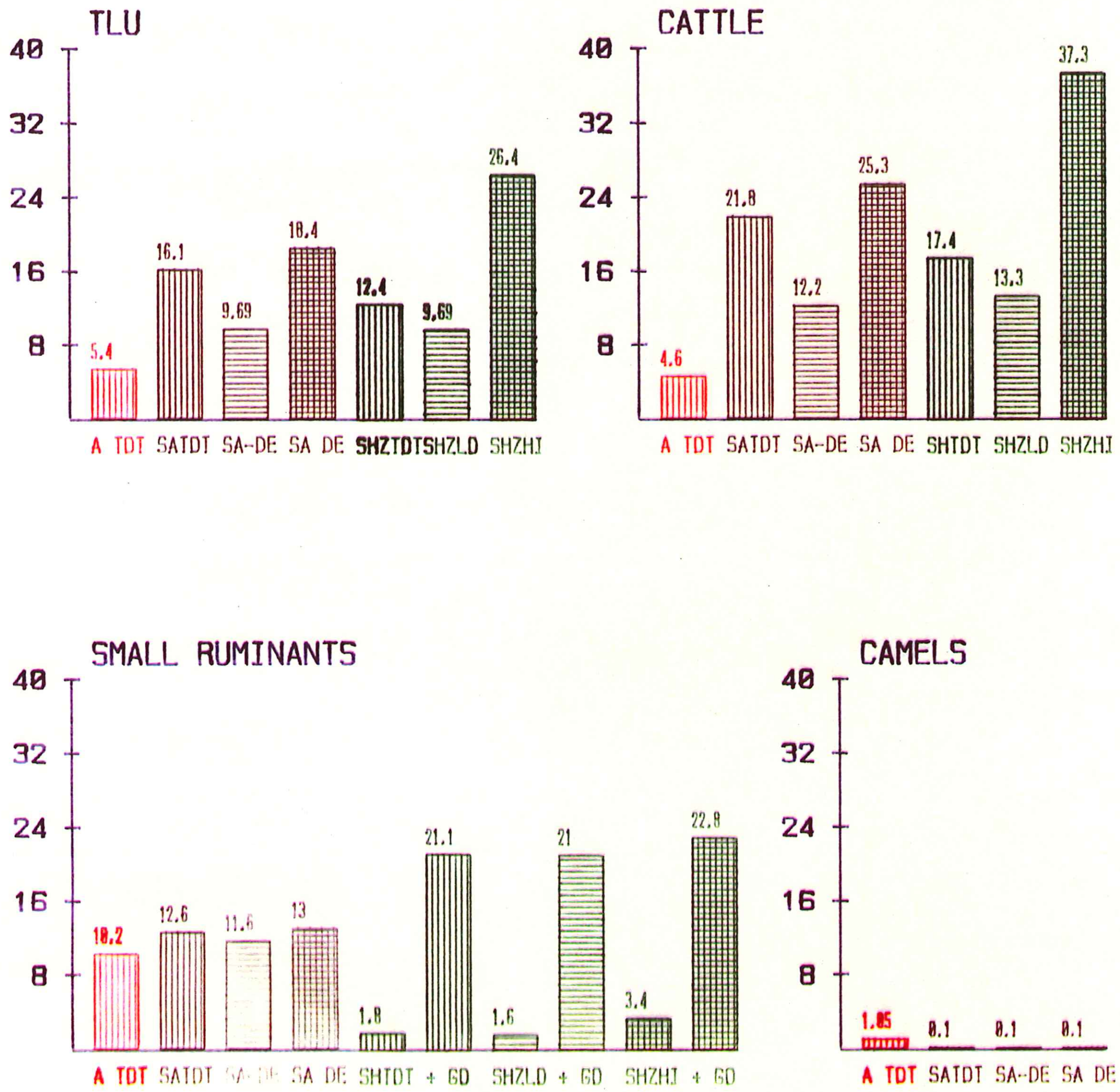
3.1.2.6 Wildlife

Aerial survey has covered more than a quarter of a million square kilometers of West Africa and each survey site has been flown at least twice. Despite this, very few wild animals of any sort have been seen, and fewer have been observed within the confines of the sampling strip. For example, in Nigeria, a total of 8 baboons, 15 warthogs and 1 elephant were recorded in six years. In the Gourma, some elephant and gazelle were seen, and in Niger, some gazelle were observed, but in the other sites, wildlife observations were conspicuously absent.

The average flying height of the livestock surveys is rather more than is considered optimal for counting wild animals, and so it is likely that a proportion were missed. Despite this, aerial survey suggest that wildlife do not constitute a significant fraction of the animal biomass in any of the sites surveyed.

FIGURE 4

ANNUAL MEAN LIVESTOCK DENSITIES IN WEST AFRICA



3.1.3 Ratios and Proportions of Livestock Species.

While it is certainly possible to contrast absolute densities of different livestock species, it is generally considered preferable to standardise the units used in terms of biomass, so that comparisons are more meaningful in terms of their demands on the environmental resources and their contribution to the economic framework of the livestock sector. Thus the ratios and proportions discussed below are expressed in terms of each species' contribution to the total number of Tropical Livestock Units (TLU's). Following Jankhe (1982), camels are taken as unity, cattle as 0.7TLU, donkeys as 0.5TLU and sheep and goats as 0.1TLU.

It has been long asserted that the contribution of cattle to total TLU levels within the West African pastoral zone is smaller in the north than in the south. This is due to a substantial increase in the relative densities of sheep and goats in both the Semi-Arid and Arid Zones, and camels in the Arid Zone only. The results of the aerial survey counts (Figure4,5.6 and 7) conform well to this pattern.

In the Arid Zone, cattle account for an average of 59-61% of the total livestock biomass, according to season, with small ruminants and camels each contributing 18-20%. In the wetter Semi-arid Zone, outside the Mali Delta, the proportion of total TLU attributable to cattle rises to 82-90%, with the remainder being largely sheep and goats. The northernmost survey site in this Zone supports the lower proportion of cattle (79-87% in Niono as opposed to 88-96% in the Nigerian Grazing Reserve areas), and in both sites, the wet season livestock populations contain proportionately more cattle biomass than do the corresponding dry season ones.

In the Delta region itself, the proportion of cattle is yet higher, at 89-94%, with, again, the remainder being essentially pastoralists' sheep and goats. In this area, however, in contrast to the sites external to the Delta, cattle are more predominant in the dry season than in the wet season.

In the Sub-Humid Zone, if only the pastoralist's animals are considered, the livestock are almost exclusively cattle - a maximum of 2.6% of the biomass is attributable to small ruminants. If, however, the goats belonging to arable farmers are included, and if the goat densities can be assumed to be similar in southern Gongola and the ILCA Case Study Areas in Nigeria's central corridor, then the proportion of cattle in the low lying survey sites falls to 80-82%. This figure is closely comparable to that found in the non-Delta sites in the Semi-Arid Zone. In the wet season refuge areas of the high grasslands, however, the proportion of cattle is rather higher - 86-93% - a figure very similar to the dry season refuge of the Mali Delta.

3.1.4. Total TLU Density.

In compiling Table 4 some adjustments have had to be made to the original information, as some of the earlier Nigerian surveys did not collect standardised information about sheep and goats. The TLU values described here do not include arable farmers goats.

Given the preeminence of cattle within the livestock sector, it is not surprising that the seasonal and spatial patterns of TLU density largely reflect those of cattle. The Arid Zone thus supports the fewest TLU per square kilometer, with a yearly mean of 5.4, and wet season densities exceed dry season ones by a small absolute margin, but in percentage terms, by approximately one fifth. Because of the relatively large number of camels in the NRL, the total TLU densities in this region are slightly higher than those found in the Gourma, i.e the reverse of the situation seen when cattle only are considered.

In the two southern ecological Zones, as with cattle alone, the mean yearly TLU densities of the non-refuge areas are virtually identical at 9.7-9.8 per square kilometer. However, the wet season densities in the Semi-Arid Zone sites are some 50% higher than the dry season estimates, whereas in the lowland Sub-Humid Zone areas, there is no evidence of substantial seasonal change. This picture is altered somewhat if the contribution of arable farmer's goats is incorporated into the Sub-Humid Zone calculations, when the overall TLU densities are increased by some 20% to 11-12 per square kilometer.

In the refuge areas of the Semi-Arid Mali Delta, and the Highlands, mean annual TLU levels are 18.4 and 26.4 (excluding arable goats) per square kilometer respectively. As might be expected, substantial seasonal changes are manifest in these localities. The lower levels are similar, at 16.1-16.4 TLU per square kilometer during the wet and dry seasons in Mali and Nigeria respectively, but the peak densities are dissimilar, at 20.7 and 36.4 per square kilometer.

3.1.5 Distribution Patterns.

Broad descriptions of seasonal cattle densities of the sort described in sections 3.1 - 3.4 are useful for comparative purposes, and for assessing the scale of development interventions neccessary to adequately provide for the livestock sector in a particular area. They do, however, conceal considerable local temporal and spatial variations. Further, little change in seasonal densities does not necessarily imply that the animal populations are static.

It is not the purpose of this review to examine such spatial patterns in detail, but the examples of distributions within selected areas, as discussed below will serve to illustrate the point, as well as demonstrate the value of the survey techniques.

The speed with which the areas are covered means that, in general, little movement can occur within the survey period, and so the distribution patterns obtained effectively reflect the current situation. This cannot necessarily be said of distribution patterns gleaned from ground survey techniques, because these take a long time, and so significant movement can occur within a survey time-frame. At worst, this can mean that some animals are entirely missed, and others counted twice.

Reliable distribution maps can serve many uses. For example, before the 1983 dry season survey of the Gourma, it was thought that the livestock populations in the area were restricted to specific localities, largely as a result of the preceding drought. In fact, though minor concentration areas were identified to the south of Gao, and around Hombori, cattle were found to be generally well dispersed throughout the region. This belied the initial assumption, and its implication on the probable effects of the drought on the availability of grazing within the survey area.

Analysis of the cattle distribution patterns in the NRL identified several phenomena. Firstly, in both wet and dry seasons, a marked southerly concentration of livestock was observed - 75-85% of the total cattle population was recorded in the southern half of the survey site. The seasonal patterns

FIGURE 5

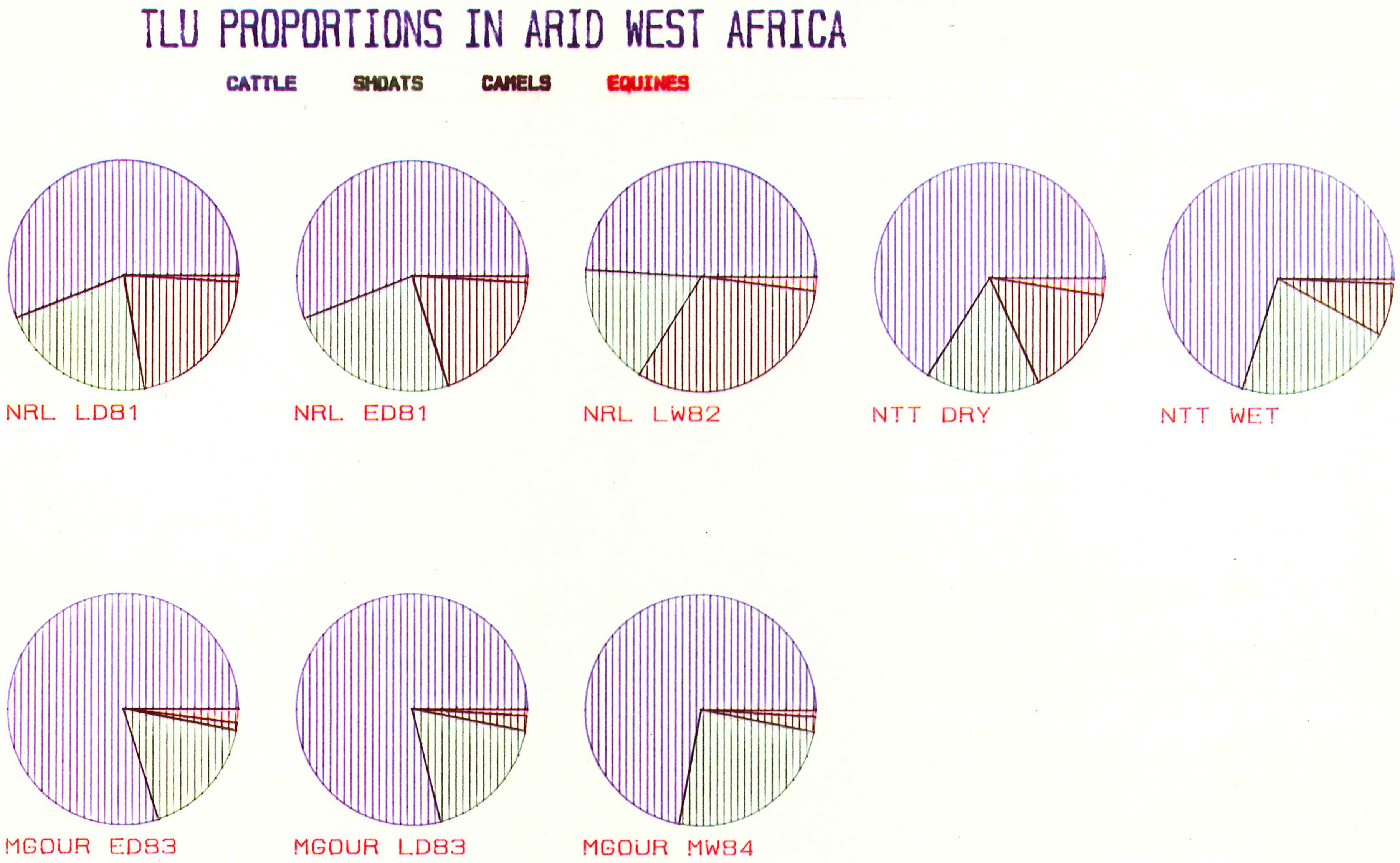

TLU PROPORTIONS IN ARID WEST AFRICA
CATTLE
SHOATS
CAMELS
EQUINES
NRL LD81
NRL ED81
NRL LW82
NTT DRY
NTT WET
MGOUR ED83
MGOUR LD83
MGOUR MW84

FIGURE 6

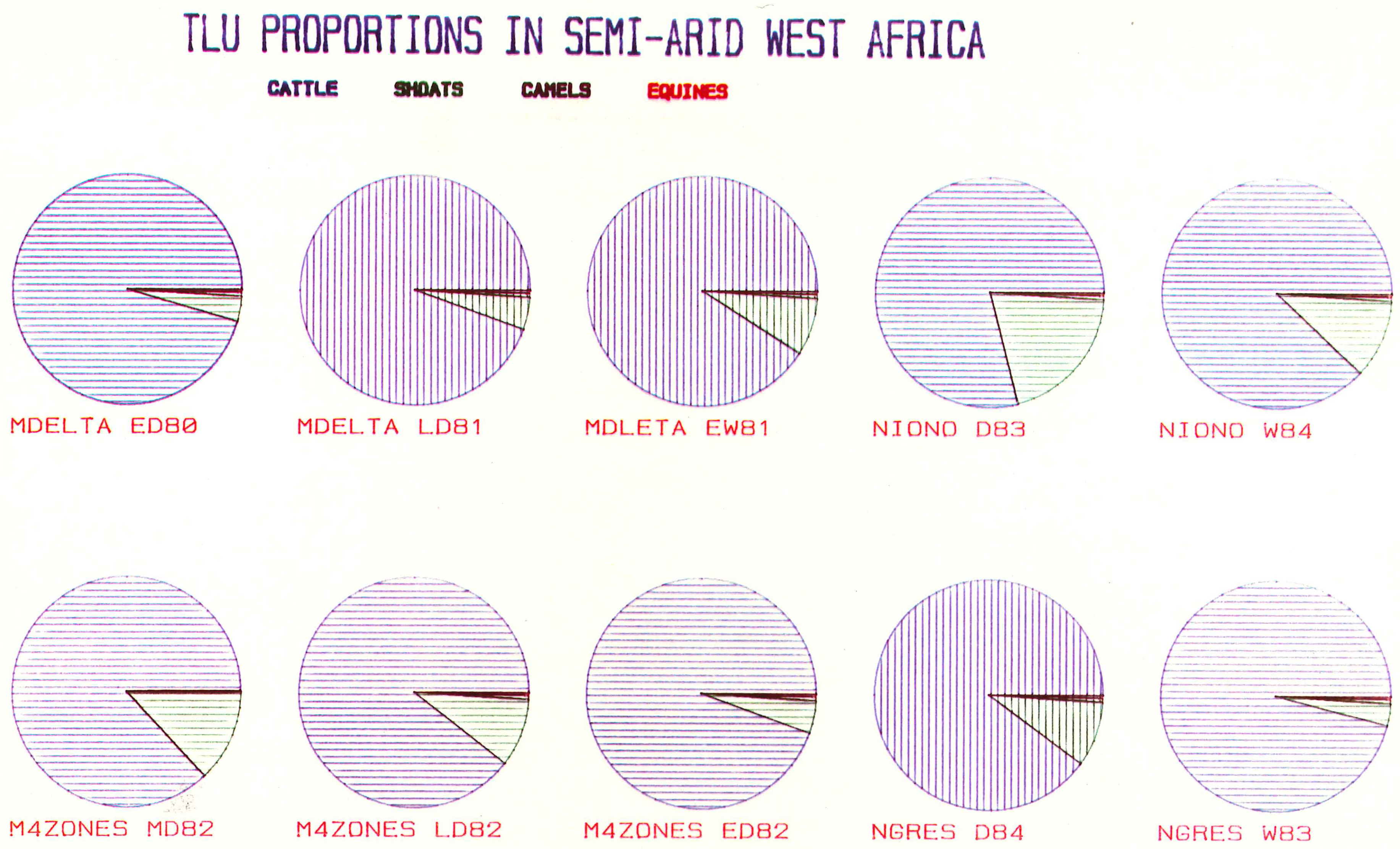
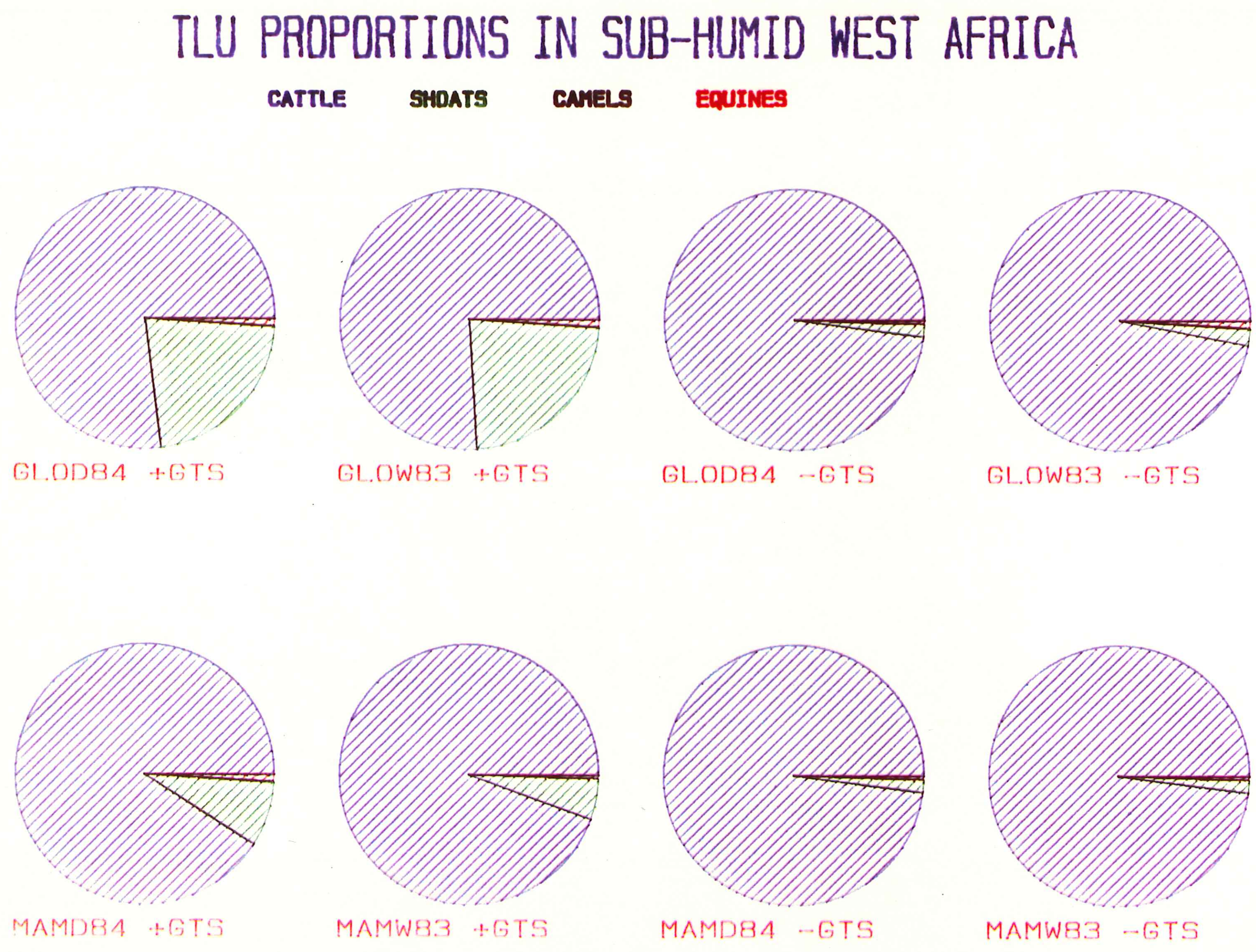

TLU PROPORTIONS IN SEMI-ARID WEST AFRICA
CATTLE
SHOATS
CAMELS
EQUINES
MDELTA ED80
MDELTA LD81
MDLETA EW81
NIONO D83
NIONO W84
M4ZONES MD82
M4ZONES LD82
M4ZONES ED82
NGRES D84
NGRES W83

FIGURE 7


TLU PROPORTIONS IN SUB-HUMID WEST AFRICA
CATTLE
SHOATS
CAMELS
EQUINES
GLOD84 +GTS
GLOW83 +GTS
GLOD84 -GTS
GLOW83 -GTS
MAMD84 +GTS
MAMW83 +GTS
MAMD84 -GTS
MAMW83 -GTS

were essentially similar, despite an increase in the population levels during October. The extra animals resulted in greater concentrations in specific areas, such as east of the Tahoua-Agadez road and around Tahoua iteslf, rather than an overall expansion to previosly unutilised pasture.

Another feature of the bovine population in this area was the striking difference between the distribution of Azawak and Bororo cattle. The Azawak were concentrted in a relatively distinct area to the south west, between Tahoua and Tchin Tabaradene, while the Wodaabe-owned Bororo were aggregated more to the south and east between Tahoua, Abalak and Aderbissinat. Preliminary results from a recently completed survey of this site (September 1985) show that, following the droughts of 1983-4, the overall distribution of all cattle was much reduced, and was confined exclusively to the most southerly portion of the area.

Striking spatial distributions were also seen in southern Gongola State, Nigeria. The cattle in this area were found in three major concentration areas - the southern highlands of Mambila, the north-eastern lowlands surrounding Ganye, and the north-western floodplains and associated lowlands of the Benue, Taraba and Donga Rivers. This pattern changed little with season, thus contradicting previosly held hypotheses that the north western lowlands were exclusively dry season grazing lands, though there was some evidence of increased dispersion during the dry season, when the more heavily forested areas were conceived by the pastoralists to be free of tsetse. It was also possible to isolate specific dry season livestock foci, around Suntai, which ground survey identified as areas of newly flushing grass utilised by primarliy nomadic pastoralists. Further, as in the Niger Pastoral Zone to the north, the aerial survey established markedly different spatial distributions of red (rahaji) and white (bunaji) cattle, the former being largely restricted to the relatively favourable pastures of the southern uplands.

3.1.6 Stratification.

Yet another valuable use of aerial survey data is the provision of livestock population estimates within selected geographical or environmental strata, such as administrative regions, land systems, areas of varying cultivation intensity, or grazing land within specific distances to water or even roads. It should be emphasised that much of the possible flexibility of such stratification derives from the use of a systematic but unstratified sampling strategy, which allows for the identification of relevant strata after the surveys are completed.

Such analyses have been performed extensively in all the large surveys flown, perhaps the most complex of which was in the Mali Delta. Space permits only three illustrative examples to be briefly summarised in the following paragraphs - the NRL, the Gourma region of Mali, and southern Gongola State in Nigeria. The detailed figures can be found in the relevant survey reports.

In Niger, basic ecological conditions were initially used to identify four Land Management Strata, which were further sub-divided into ten Land Management Units which were geographically distinct, yet internally homogeneous. In the Northern Ighazer Flood Plains Stratum, cattle populations fell by some 40% between wet and dry seasons, largely due to a drop in Bororo population levels. In contrast, cattle in the Central Savanna Stratum rose by some 34% during the same period, again due to a change in Bororo density, but also to a simultaneous fall in Azawak numbers. In the Tahoua Upland Stratum, dry sesaon cattle populations also rose during the dry season, by a factor of 1.5, but this time because of an equal increase in both Bororo and Azawak cattle densities. In the fourth Land Management Stratum - the Sand-dune Grasslands - little if any seasonal variation in cattle numbers of either breed was recorded.

The survey methodology employed also allows for the re-definition of strata, should initial assumptions prove inadequate or mistaken, or additional data become available. Such was the case in the NRL Project Area just described, when the area was divided into eight Herders Association Regions, as proposed by Maliki, after the 1981 surveys, and before the 1982 flights. Three of these Regions - Abalak, Tchin Tabaradene and Amataltal - sustained more or less constant populations in May, September and October; the Tassara and Ingal Regions contained substantially fewer cattle in October, while the livestock populations in Bermon at this time were approximately twice those found in May and September; and the Tofamenir Region was clearly identified as a wet season concentration area.

The Gourma livestock populations during the wet season were stratified according to Administrative Departments, rainfall zones, ecological regions, and degree of pastoral pressure, as derived from Hiernaux and Cisse (1983) and Wilson et al (1983). Cattle densities were shown to be at their maximum in areas with 400-500mm annual rainfall (10.3 per square kilometer), and on land with either intense or very weak pastoral pressure (6.1-6.8 per square kilometer). They were substantially lower in regions with average or weak pastoral pressure, and in areas with relatively high or comparatively low rainfall. Sheep and goats, by contrast were most abundant in areas of average or intense pastoral pressure, and in land with more than 600mm of rainfall per year.

The stratifications used in southern Gongola were many and varied. Two examples are vegetation and land use type, as derived from Side Looking Airborne Radar maps and also used in the low intensity Zone-wide surveys; and distance to roads and towns, as extracted from 1:250,000 cartographic maps. The highest livestock densities, in both wet and dry seasons, were found in the open grasslands, with substantial, but progressively lower numbers in the highly cultivated and moderately wooded areas. In the dry season, small, but dense populations of Sokoto Gudali were recorded in dense forest, presumably utilising the abundant browse which forms an important part of their diet. With respect to roads and towns, the cattle densities in both wet and dry seasons were at their highest (22-27 per square kilometer) close to, but not actually next to major roads and towns. The densities dropped rapidly away from towns, and rather less markedly, particularly in the wet season, away from major roads.

3.1.7 Long and Short Distance Movements.

Evidence for livestock movements can only sometimes be gleaned from aerial survey results in the absence of complimentry ground information. In the Mali Delta, for example, a knowlegde of the seasonal changes in overall numbers within the survey region as a whole, combined with quite striking contrasts in spatial density patterns made it possible to infer comparatively complex movement patterns of both cattle and small ruminants. Thus, the progressive rise in the cattle densities within the Inundated Plains, alongside a fall in the densities found in the Upland Sahel (Zone Exondees) and Transitional (Franges Ouest) Zones reflects an influx of animals into the floodpalins during the mid and late dry seasons, from the upland and transitional pastures that act as way-points between wet and dry season grazing lands. Further, these results showed a progressive bifurcation of the dry season cattle population, as they moved either north-east or south-west to the basins with 'bourgou' pasture from the central basin west of Mopti.

In the Niger Pastoral Zone, while some indication of seasonal transhumance patterns could be implied from spatial density patterns, such as a wet season aggregation in the Tofamenir Region, more could be gleaned from the changes in the proportions of the two major cattle breeds. Thus, in general, the Azawak cattle populations were largely sedentary in most of the Zone, while the Bororo animals moved considerably from area to area.

Inferences from seasonal changes in livestock density alone can, however, be misleading in the absence of ground truth data. Thus, in the ILCA Case Study Areas of central Nigeria, high wet season cattle densities in the Mariga, Lafia North East and Giwa-NAPRI sites was initially interpreted as an influx of non-resident transhumant pastoralists. Ground survey established that this pattern was, in fact, due to the return of resident stock owners from dry season pastures near the Benue-Niger confluence to the south.

Ground information was also necessary to identify detailed movement patterns in southern Gongola State, where overall seasonal distribution patterns were essentially similar. Here, it was found that the majority of transhumance movements were internal to relatively discrete cattle systems, and seldom exceede 50-100 kilometers, with the exception of those animals which were taken down from the highlands in the dry season. Further, most transhumance movements were tripartite, from wet season pastures to areas of early flushing grass, and then on to dry season grazing areas.

3.1.8 Long Term Changes in Animal Population Levels.

Only in Niger, and the ILCA Case Study Areas in Sub-Humid Nigeria, have the intervals between surveys been sufficient to shed light on any long term changes in livestock population levels.

Preliminary results from the 1985 wet season survey indicate an approximate drop of 75% in overall livestock levels following the '83-'84 drought. The species most dramatically affected was cattle, though both camels and small ruminants were also substantially reduced.

Differences were also observed in Nigeria between the levels recorded in 1979 and 1984, but because of the probable impact of rinderpest and drought, they are difficult to interpret. The discussion presented in RIM (???) concludes that a long term increase in the cattle population may be evident.

3.2 THE HUMAN POPULATIONS

3.2.1 House Types and their Interpretation.

The enumeration of human populations and their productive systems depends on the correct description of the forms of houses or compounds, as well as a knowledge of the number of occupants in each observed unit. If house types can be reliably identified from the air, estimates can then be made of specific human populations, and of the numbers and distributions of varying types of production systems. The ethnic composition of their inhabitants remains an inference, but groundwork has generally shown a strong correlation between house type and ethnic group, except for some specific examples mentioned below.

This is most easily achieved where types of dwelling are few in number, and where previous ground work has already established the significance of their appearance. In the the case of thePastoral Zone of Niger, aerial survey can readily distinguish the principal types of Tuareg and WoDaaBe dwellings. Since these are associated with distinctive types of animal production, satisfactory enumeration can be carried out from the air. In the case of Gongola State, Nigeria, where no previous knowledge was available, and where the numbers and types of house and production system are extremely varied, only simplified categories can be distinguished from the air.

One of the important features of aerial survey is that it should provide data on the current populations of an area. Temporary but distinctive dwellings, such as leather tents, and permanent mud houses with associated crops are easy to assess for current habitation, but camps like the brushwood crescents of the WoDaaBe in Niger may take many years to degrade sufficiently to appear abandoned. Conversely, temporary resting places with little or no physical structure may be overlooked.

The interaction of populations can lead to the adoption of structural types of another ethnic group. Thus, in Gongola State, nomadic fishermen on the Benue were found to build shelters similar to those of nomadic pastoralists. In the NAPRI study area west of Zaria, FulBe pastoralists were found to build the same square mud houses as their Hausa neighbours. In addition, because nomads engaged in transhumance split their herds and family units during the dry season, each group may be responsible for several dwellings at once. Thus, FulBe stock owners who live south of Bauchi have square mud compounds with associated crops, where they farm during the rainy season. When they take their herds on transhumance to the Benue River, they build beehive rugas on the sandy shore. These are solid structures with associated ruminant shelters that are made to last for up to eight months. In the first two months of the rainy season, the younger sons are sent further south with the main herds so as to exploit the first flush of grass. These herdsmen build temporary shelters, often characteristically covered with blue plastic sheets. These three types of dwellings are thus used simultaneously by a single productive unit, and so can only be analysed to give population totals with the input of ground based information.

French authors have devoted more detailed study to architectural categories and the most comprehensive source on dwelling types and productive systems is Brasseur (1968), who studied the dwellings that were current in Mali during the 1960's. He also mapped their distribution and explored their association with types of productive system. He devised a colour-coded key for describing both the size, disposition and construction of house types. In the case of Niger, Bernus (1981:125 ff.) has carefully described the different types of shelter or tent constructed by the Tuareg. It is regretted that no comparable work exists for other regions that have been the subject of aerial survey.

The following table sets out the classes of dwelling that have been distinguished during aerial surveys, and comments on their association with a productive system.

TABLE 7. THE TYPES OF DWELLINGS DISTINGUISHED DURING AERIAL SURVEYS

TYPE OF DWELLING	ETHNIC GROUP	PRODUCTION SYSTEM
1.NONE		
a) Shelter under trees	FulBe	Nomad/Transhumant
b) No shelter but distinctive outline of crescents	WoDaaBe	Pastoralism
2. TENTS		
a) Leather + lateral poles	Tuareg	Nomadic Pastoralism
b) Cloth without lateral poles	Moor	Nomadic Pastoralist
3. MATTED OR GRASS STRUCTURES		
a) Hemispherical framework + woven palm matting	Bella (Gourma) Tuareg (Niger)	Settled pastoralist Nomadic Pastoralist
b) Small hemispherical framework + plastic sheeting	FulBe	Nomad/Transhumant
c) Larger beehive ruga + ruminant shelters	FulBe	Nomad/Transhumant
d) Oval framework + matting	Sonrai	Arable + livestock
e) Rectangular framework + matting	Bella (Niger)	Nomadic pastoralist
4. MUD HOUSES		
a) Small, round, densely packed	Dogon	Arable
b) Round, thatched + corrals	FulBe	Settled/Transhumant
c) Round, thatched + crops + corrals	Samba, Mambila FulBe	 Agropastoral
d) Round + Crops	Various	Arable
e) Rectangular, flat roofs	Sonrai, Hausa	Arable

Notes:

1. The house types of arable farmers in Gongola State and the Nigerian Sub-Humid Zon are extremely varied and numerous, and cannot easily be classified without furthe detailed research. However they are generally restricted to arable farming, and rais only small ruminants or pigs, and may therefore be fairly treated as a single class. A few ethnic gropus are very distinctive, such as the Tiv, and can be linked closel to the culture of root crops.

2. The presence of tin roofs was recorded in some surveys in Nigeria, but ground wor revealed that this was not, as intended, a reliable predictor of wealth, but rathe reflected the relative rainfall. Nationally this is probably true, but within a give rainfall region, tin rooves are likely to reflect both disposible income an accessibility.

The following table gives the presence or absence of house types in the surveyed areas.

TABLE 8 HOUSE TYPES RECORDED IN SURVEYED AREAS

HOUSE TYPE	Delta	Gourma	NRL	SHZ	Gongola
1a	-	-	+	+	+
1b	-	-	+	-	-
2a	+	+	+	-	-
2b	+	-	+	-	-
3a	-	-	-	-	-
3b	-	-	-	+	+
3c	+	+	+	+	+
3d	-	-	-	-	-
3e	-	-	+	-	-
4a	+	+	-	-	-
4b	+	-	-	+	+
4c	+	-	-	+	+

In the following sections, the more detailed structural or ethnic categories of habitation type, as discussed above, have been amalgamated into four major ownership groupings: arable farmer: fishermen: agropastoral: and pastoral. This last group has been further divided, where possible, into "settled" and "nomadic". In the Nigerian Sub-Humid Zone, the great diversity of structures and the comparative paucity of relevant information precludes the effective categorisation of house types by structural or ethnic characters. Thus, in this Zone, the presence or absence of associated crops and cattle corrals has been used to assign habitations to one of the four production categories mentioned above. Some distinction between dwellings belonging to 'settled' and 'nomadic' pastoralists has been made on the basis of apparent permanence - beehive rugas and permanent mud structures being classified as settled, and shelters made from cut branches or crop stalks being classed as nomadic. It should be emphasised that the terms settled and nomadic as used here are therefore related to the duration of residence in an area, and not necessarily to the mode of livestock husbandry.

3.2.2 Abundance, Density and Distribution of Human Habitation.

3.2.2.1 Pastoralists

On a Zonal basis, the average annual density of purely pastoralists' huts (i.e excluding agropastoralists) increases southwards, from 0.4 per square kilometer in the Arid Zone to 0.58 per square kilometer in the Semi-Arid and 0.76 per square kilometer in the Sub-Humid Zone (see Table 9). Such a result might be expected from the parallel trend in livestock densities described in section 3.1.2.1 above (but see also section 3.2.3 below).

Separating out the refuge areas of the Mali Delta and the Highlands, the estimated pastoralist habitation densities in these sites are 0.46 and 1.42 per square kilometer respectively. Those of the non-refuge localities become 0.90 and 0.70 per square kilometer for the Semi-Arid and Sub-Humid Zone sites respectively. The difference between the refuge and non-refuge values contrast sharply with the equivalent differences in cattle densities which may be

TABLE 9 THE ANNUAL AND SEASONAL MEANS FOR HUMAN HABITATION DENSITIES RECORDED FROM AERIAL SURVEY AND THEIR RATIO TO LIVESTOCK DENSITIES
(Densities as numbers per square kilometer)

SITE, REGION	Arab	DRY SEASON Past	tlu/p	a/p	WET SEASON Past	tlu/p	a/p	ANNUAL Past	tlu/p	a/p
ARID ZONE										
Niger RL	0.16	0.47	10.9	0.3	0.49	12.2	0.3	0.48	11.6	0.3
Gourma	0.42	0.33	14.1	1.3	0.38	15.5	1.1	0.36	14.8	1.2
Total	0.29	0.37	13.1	0.8	0.43	13.7	0.7	0.40	13.4	0.8
SEMI ARID ZONE										
Delta		0.59	35.2		0.33	48.3		0.46	39.9	
Niono		0.55	18.7		0.69	22.6		0.62	20.8	
NLPU Gr Res	13.0	0.94	4.43	13.8	1.42	8.47	9.2	1.18	7.36	11.0
Total		0.63	26.1		0.53	32.2		0.58	29.7	
Total-Delta		0.74	8.99		1.06	14.4		0.90	12.8	
Bauchi State	19.3				0.60		32.2			
SUB-HUMID ZONE										
Gongola low	10.5	0.30	26.0	35.0	0.39	17.7	26.9	0.35	21.14	30.4
Case Areas	14.0	1.28	10.2	10.9	1.44	9.93	10.8	1.36	10.5	10.3
All lowlands	11.6	0.65	14.9	17.8	0.76	13.1	15.3	0.71	13.8	16.3
HIGHLANDS@	23.3	0.99	16.6	23.5	1.85	19.7	12.6	1.42	18.6	16.4
TOTAL in SHZ	12.2	0.68	16.0	18.1	0.85	17.0	14.4	0.76	17.0	16.1
Gongola low*	10.5	0.61	16.0	17.2	0.7	12.7	15.0	0.66	14.13	16.0
HIGHLANDS*@	23.3	1.3	17.9	17.9	2.16	19.4	10.8	1.73	20.9	13.5

@ Figures for Mambila only
* Includes agropastoralists and arable goats

explained in terms of the size and composition of livestock herds owned. Further, some non-pastoralists may own cattle.

Within the individual Zones, there is considerable variability between sites, at least with respect to the annual mean densities. Thus the NRL holds some 31% more pastoralist dwellings than does the Gourma Region of Mali, despite their very similar cattle densities, presumably reflecting the higher TLU densities to be found in the Niger site, and the presence of large numbers of camel owning Tuareg. Within the lowland areas of the Sub-Humid Zone, there is even greater variablility, from 0.35 to 1.36 per square kilometer, in Gongola and the ILCA Case Study areas respectively, despite a relatively modest, though certainly paralell, rise in livestock densities. This supports the contention of Milligan and Bourn (1983) that the central corridor of Nigeria is a substantial focus of pastoralism in the Sub-Humid Zone.

There is also much variation in pastoralist habitation density with season, due to the degree of transhumance in the various Zones. These, in general, parallel the changes in livestock density. In all the site groupings within the Sub-Humid Zone, wet season pastoralist habitation densities exceed the dry season ones by some 15% in the lowlands and up 87% in the Mambila Highlands. Little seasonal variability is evident in the Niger Pastoral Zone; the Mali Delta supports more pastoralist habitations in the dry sesaon than it does in the wet season, whilst in the other Semi-Arid Sites, the reverse is the case.

In summary, therefore, the seasonal variations in the total recorded density of pastoralist habitations parallel those of the livestock within the various survey zones. However, the same cannot be said for the observed variability between sites. This argues that the relative sizes of the livestock and pastoralist populations are not constant throughout West Africa, a phenomenon which will be treated in more detail in section 3.2.3 below.

As far as the different types of pastoralist habitation are concerned, it has proved possible to extract comparable data for some sites only. In the NRL, the proportion of nomadic pastoralists is comparatively high during the dry season - some 65%, dropping to 52% during the wet season. This fall probably reflects an increase in the apparent permanence of the strucures observed, rather than any rise in the proportion of permanently sedentary pastoralists.

In the Sub-Humid Zone, the proportion of habitations assigned to the purely nomadic category was very variable from place to place and from season to season. In general, it was found to be lower than those recorded in the Arid Zone, seldom exceeding 40% in the Case Study Areas, though reaching 66% in the Gongola Lowlands during the dry season. In the Highlands, no purely nomadic pastoralists were seen at any time. Because of the variability, no simple pattern emerges beyond that implied by the figures above, i.e that eastern Nigeria contains a higher proportion of nomadic pastoralists than does the central part of the country, and that the nomads are effectively absent or excluded from the highland areas.

The proportion of short term residents in the Sub-Humid Zone varies markedly with season in most of the survey sites covered during 1983 and 1984. In the central sites, these more nomadic stock owners are found in higher proportions during the dry season, whereas in Gongola, and indeed in the Semi-Arid Grazing Reserves just to the north, the reverse is generally the case. This may well reflect the flexibility with which the nomads can respond to local conditions.

Such data supports the generally held hypothesis that nomadic cattle owners are better able than the more sedentary ones to utilise the more marginal pastures, as represented by the eastern portions of Nigeria and the dry grazing lands of the Arid Zone in Niger.

The division of pastoralist habitation into 'nomadic' and 'settled' categories is the only one possible in regions like the Sub-Humid Zone, where the great majority of pastoralists are of the same ethnic extraction, and the remainder have learned their skills from the majority group. This means that the structural charcteristics of the habitations built by pastoralists of different social origins are indistinguishable, at least from above. In the other Zones this stricture does not apply to the same degree, and so an alternative way of subdividing the pastoralist populations is to consider the distribution of different types of habitation structure without necessarily assigning to them a specific mode of livestock production. Such a procedure still allows for the identification of discrete subpopulations, but avoids the danger of making too many assumptions based on habitation permanence, which may lack adequate ground truthing.

A good example of such differentiation is provided by the results from the Niger Pastoral Zone. In these surveys, despite initial difficulties in hut-type identification, it proved possible to separate out two pastoralist populations, the Tuareg and the WoDaaBe. The distribution of each ethnic group was effecetively mutually exclusive, and further, coincided closely with one of the two cattle types recorded. Thus, the WoDaaBe could be linked to the Bororo cattle, and were largely found in the south eastern sector of the survey site, while the Tuareg could be linked to the Azawak cattle, which were predominant in the west. The Tuareg dwellings could be further divided into three categories:- those reflecting a sedentary lifestyle, which were found only in the south western corner of the survey area; matted camps, which were concentrated in the east; and tented camps, which were found to have a largely western distribution in both wet and dry seasons.

The pastoralist populations of the Gourma region in Mali could be divided along similar lines. Here, the FulBe (Peuhl) were restricted to the west and south western part of the site, while the Tuareg (Tamasheq) and Bella habitations were well dispersed throught the area, and were more abundant during the wet season, and early dry season. Of the arable farming groups, habitations ascribed to the Sonrai (Songhai) were strictly limited to the environs of the Niger river, while the Dogon dwellings were found only in the southwestern corner between Hombori and Douentza.

Thus, of the two major pastoralist groups found in the two Arid Zone sites, there are some striking similarites in distribution pattern. The Tuareg tend to be well dispersed, while the WoDaaBe are generally more prone to aggregation within specific spatial limits. A third, but much less numerous, group found in both the Gourma and the NRL - the Moor Arabs (Maure) - also shows characteristic distribution patterns, being generally limited in the northern sector of each survey site.

The distribution patterns of the habitation ascribed to the different ethnic groups cannot always be so easily differentiated. In the Mali Delta, for example, the Tuareg and Peuhl dwellings were generally intermingled, and though the areas of concentration changed with season, the basic trends in inferred movement were similar for both groups. This reflects the refuge status of the Delta, which because it is relatively small, and because of the flooding patterns, imposes essentially fixed strategies of pasture use on both pastoralist peoples.

3.2.2.2 Agropastoralists

Agropastoralists are considered to be of particular interest because they include both pastoralists who grow crops, and arable farmers who raise livestock. They thus represent an overlap between two traditionally separate, and sometimes incompatible, production systems which may reflect a way of both reconciling differences, reducing conflicts and increasing the intensity of land use. Arguably, a movement towards mixed farming systems is one of the more desirable future trends in African agricultural development. As such, agropastoralists have been a focal point of a considerable amount of ILCA research, and a source of substantial national and international interest, particularly in Nigeria, where the eventual sedentarisation of the pastoralist population is seen as a National priority.

In the Sub-Humid Zone agropastoralist estimates from the air are more compatible with the counts of the other habitation types. As for the nomadic stockowners, the proportion of agropastoralists varied a great deal (0-71%) with both site and season. In broad terms, there are more agropastoralists in eastern than central Nigeria. They are concentrated in three areas, the Ganye Lowlands (Samba), the Mambila Highlands (Fulani and Mambila) and within the "central corridor" itself, the more remote sites to the south and west of Kaduna. In these areas the proportion of these farmers is commonly between 50 and 80%. In contrast, the Case Study areas along the Zaria-Lafia axis, particularly those near Kaduna, hold relatively few agropastoralists, as do the lowland areas of southern Gongola bounded by Gossol, Serti and Donga. In the majority of areas, the wet season proportions are lower than those of the dry season, reflecting the fact that many of the agropastoralists are in fact transhumant pastoralists who grow crops to supplement their income from livestock.

3.2.2.3 Arable Farmers

Comparable figures for the densities of arable farmers - those who do not raise cattle, though they may keep other forms of livestock such as pigs or small ruminants - are available for the Gourma Region of Mali, for the NRL, and for the sites surveyed in Nigeria. These latter areas include Bauchi State in the Semi-Arid Zone, which was not surveyed for livestock. These figures make it possible to compare arable farmer densitiy in all three ecological Zones, though not using exactly the same Semi-Arid Zone dataset that supplied the pastoralist and animal estimates.

These figures suggest that the arable farming population is at its most dense in the Semi-Arid Zone, at 18.71 per square kilometer, as compared with 0.29 per square kilometer in the Arid Zone, and 11.6 per square kilometer in the Sub-Humid zone. As ever, the reliability of these figures depends on the fact that the areas surveyed are truly representative of the Zones. The estimates for the arable farmer population for the Semi-Arid Zone of Mali quoted in ILCA (1981) suggest a maximum density of 12.3 per square kilometer, i.e some 50% less than that quoted above. However, given that the densities for both the animal and pastoralist populations estimated from the air are also rather higher than the ILCA figures for this Zone, and given the fact that aerial survey is likely to under- rather than over-estimate population levels (see also section 3.1.2.1), it seems likely that the ILCA (1981) figures for the arable farmer populations are underestimates. This does not preclude the possibilty that Bauchi State represents an area of relatively intense arable farming, though it certainly supports a lower proportion of cultivatd land than does the Mali Delta (see section 3.3).

Within the Zones for which adequate data is available, there is evidence of some variability in the density of arable farmer habitations, though perhaps less than might be expected. Thus the NRL sustains an average of less than 0.2 arable dwelling per square kilometer as against the figure of 0.42 that is estimated for the Gourma. It should, however, be emphasised that where arable farmers are found in the Niger site, in the southwestern corner, they are found at comparatively high densities. Within the Sub-Humid Zone, the arable farmer habitation densities are remarkably uniform when large scale distribution patterns are considered, given the accepted ideas that the central "corridor" is more heavily populated than the eastern regions. The estimated figures for these two areas are 14 and 12 per square kilometer respectively.

In relation to the total numbers of pastoralist habitations (Table 9), those of the arable farmers rise dramatically from north to south. In the Arid Zone, the number of arable habitations per pastoralist dwelling ranges from 0.3 in Niger to 1.1-1.4 in the Gourma. In the Semi-Arid Zone sites this figure rises to 9-32, depending on site and season, and in the Sub-Humid areas from 10-35, again depending on site and season. This demonstrates unequivocally the outstanding importance of livestock in the Arid Zone but, perhaps surprisingly, suggests that livestock are no more prevalent in the Semi-Arid Zone than they are in the Sub-Humid Zone to its south. This is despite the long held opinion that the Semi Arid Zone is the historical centre of livestock enterprise in West Africa. One possible explanation is that both arable and pastoral peoples have moved into the Sub-HUmid Zone at the same rate, thus maintaining their relative numbers at the same levels.

Within the Sub-Humid Zone, the proportion of arable farmer dwellings is considerably higher in the remoter eastern regions of Nigeria than in its central regions. This suggests that the pastoralists have reached the eastern grazing areas comparatively recently, an assertion that is well backed by evidence from the ground, which dates the most recent FulBe incursions to the 1970's. It also implies that pastoralists follow arable farmers into areas of relatively dense vegetation as the bush is progressively cleared for cultivation, and the risks of trypanosomiasis consequently reduced.

3.2.2.4 Others

Fisherfolk, near lakes swamps and rivers, were also recorded. With one exception, they were seen in vanishingly small numbers, that exception being the Mali Delta. There, the Bozo habitation densities consistently exceeded those of any one category of pastoralist, and fairly obviously, were restricted to the immediate environs of the Rivers and Flooded Plains. In March, the total densities of all pastoralist dwellings ammounted to 80% of that of the fishermen, while in June, pastoralists exceeded fishermen by some 30%, despite a marked drop in the cattle owners' numbers. This shows that fishermen, like many pastoralists, are also highly mobile.

3.2.3 Ratios of Human and Livestock Population Levels.

The numbers of cattle actually owned by pastoralist families, or the number of animals that can conveniently be managed by the occupants of a single dwelling may vary considerably according to husbandry techniques, season, and geographical area. Such variations will be reflected in the ratios of livestock to pastoralist population levels, as well as in Grazing Unit size (see section 3.1.2.1).

The ratios of livestock to pastoral plus agropastoral population levels in the non-refuge areas of all four Zones are fairly similar when assessed on an annual basis - the range for the Zonal means being 12.8-13.8 TLU per pastoral habitation (Table 9). The seasonal variation is rather greater, but still remains considerably less than the seasonal range of either livestock or pastoral habitation densities. These figures do, however, conceal a rather greater range between sites within each Zone, which belies the initial impression of uniformity. Thus, pastoralists in the Gourma raise 14.8 livetock units per habitation, 30% than do their counterparts in the NRL; those in the central regions of Nigeria only keep some 50% of the numbers TLU per dwelling when compared to pastoralists in the lowlands in the east (21.1); whilst the equivalent figure for Niono is 20.8, as opposed to 7.4 for the other Semi-Arid site, namely the Grazing Reserves in eastern Nigeria. The number of TLU per livestock owners' dwelling in the refuge area of Mali is approximately twice that of the nearby Niono, whilst in the Mambila highlands support, at 18.6, a similar number of livestock per pastoralist habitation to that found in the surrounding lowlands.

3.3 CULTIVATION

The majority of cultivation estimates made during the aerial surveys were visual, the proportion of cultivated land within the current cultivation cycle being estimated for each grid cell by the survey coordinator. The interval class boundaries used were 0, 1%, 5%-25% in 5% steps, and thereafter in steps of 10%. Two exceptions to this visual assessment were the aerial surveys of Bauchi State, Nigeria, in 1983 and in Niger in 1985, in which cultivation and land cover proportions were assessed photographically (see section four). Examples of the results obtained are given in Section 4 as illustrations of specialised development applications. In some of the surveys, the proportion of fallow land was also estimated, though the results are not discussed in this review.

Cultivation levels were found highest in the Semi-Arid Zone, ranging from 8% in the Grazing Reserve sites in Nigeria to 23% in the Niono Study Area in Mali (see Table 10). The mean value for the Zone as a whole was 21%, and for the Delta and non-Delta Regions respectively were 23% and 16%. The Zonal mean represents 6.3 times the comparable figure estimated for the Arid Zone (3.3%), and over double that of the Sub-Humid Zone (8.9%).

There is comparatively little variablity within the Zones, with two notable exceptions. Firstly, at 8%, the cultivation intensity in the Semi-Arid Grazing Reserve Sites is much lower than elsewhere in the Zone, which is at least partly because arable famers have been actively discouraged from growing crops in these areas.

The other exception is the group of ILCA Case Study Areas in the central "corridor" of Nigeria. In these sites, 16% of the land was within the current cultivation cycle, as against 6% in southern Gongola, where there was surprisingly little difference between the cultivation levels of the highland and lowland areas.

In eastern Nigeria cultivation was more concentrated in patches, particularly near major roads, while large tracts of land are entirely devoid of crops. The low intensity survey of the whole Sub-Humid Zone reveals a very similar pattern. On an east to west axis, the margins of Nigeria are least cultivated, with an evident peak in cropping intensity along a line from Kaduna to Makurdi, i.e. around the ILCA Case Study Areas. With respect to a north/south axis, the northern and southern boundaries of the Zone are substantially more cultivated than is its core.

As in southern Gongola, cultivation in those areas with low overall cropping levels, in both the Arid and Semi-Arid Zones, is frequently very localised and patchy. In both the NRL and the Gourma, over four fifths (83%) of the grids contained no cultivated land at all. The remaining 17% were concentrated in the western and southern margins of each area, and in the Gourma, along the River Niger. Where cropping was found, it was almost always in excess of 25%, and at times reached as much as 80%. In contrast, where mean cropping levels are higher, as in the Mali Delta and Bauchi State, Nigeria, few areas are totally devoid of cultivation unless they are Reserves of some type. Thus, mean cultivation levels, within a site, may reflect the amount of land suited to arable farming as much as it does the degree to which that land is actually cultivated.

This argument should not be taken to imply that cropping is always evenly spread in those sites where cultivation levels are relatively high and so

TABLE 10 THE ANNUAL AND SEASONAL MEANS FOR LAND USE AND ENVIRONMENTAL PARAMETERS RECORDED FROM AERIAL SURVEY

SITE, REGION	%Cult	%Grass Wet	%Grass Dry	Veg Den Index	%Dry Grids Dry Season	Catt/Cult Hectare Wet	Catt/Cult Hectare Dry
ARID ZONE							
Niger RL	3.34	25.8	20.5	52.6	90	1.23	1.21
Gourma	2.45	17.6	19.2	71.6	83	2.33	1.86
Total	2.90	21.7	19.9	62.1	87	1.78	1.53
SEMI ARID ZONE							
Delta	22.6	23.0	32.0	81.5	58	1.0	1.25
Niono	23.3		32.9		70	0.84	0.51
Bauchi	17.0						
NLPU Gr Res	8.4	4.35		169.2	92	1.31	0.77
SUB-HUMID ZONE							
Gongola Low	5.52	11.5	7.34	187.9	62	1.76	1.99
Case Areas	17.5	49.3		129.9	64	1.25	1.05
HIGHLANDS	6.16	57.5	66.3	60.0	8	8.39	3.70

widely dispersed. This is well illustrated by the distribution of cultivation in Bauchi State, where it was evident that crop growing was more intense in the northern and eastern portions of the State. The calculation of the number of hectares cultivated per arable farmer dwelling shows this particularly clearly. The average value for the State was found to be 0.9 hectares; that for the relatively flat and productive Northern Zone was 1.3 hectares; and in the sothwestern areas, with shallow soils or a substantial amount of hilly terrain, the comparable value was 0.5 hectares per habitation.

The area cultivated per arable farmer dwelling in the other lowland sites of the Sub-Humid and Semi-Arid Zones for which data are available, ranges from 0.52 to 1.15. However, in the Mambila highlands it is considerably lower - some 0.26 hectares per habitation. In the Gourma Region of Mali, it is some five times higher, at 5.0 hectares per habitation, and in the NRL the comparable figure was appeoximately 19.

Many factors could influence the area tilled by the occupants of a single dwelling, from the quality of the land available, as in Bauchi and presumably the Gourma, to the degree of competition for space, as may be the case in Mambila. These results are, however, striking in that they show a marked increase in the area farmed per arable habitation in the more northern study sites.

In relation to cattle densities, cultivation percentage varies, on an annual basis, from 0.7 in Niono to 9.8 in Mambila. This indicates that in the former, cultivation is the predominant agricultural sector, while in the latter, it is pastoralism which dominates land use. In the remaining sites, this ratio is surprisingly constant (1.1 -2.3) which suggests that, on average, similar proportions of land are used by the arable and pastoral sectors in most of the study sites, irrespective of ecological Zone. This, in turn, implies a correlation between cattle densities and cultivation levels which will be discussed in section 3.5 below.

The conclusions that can be drawn from these figures differ substantially from those implied by the ratios of pastoral and arable habitation densities described in section 3.2, which suggest a dramatic fall in the proportion of pastoralists to the south. Thus while the relative proportions of land devoted to each sector may be fairly constant, the populations supported by them varies considerably. This may reflect the increased productivity of cultivated land in the southern Zones.

3.4 ENVIRONMENTAL CHARACTERISTICS

A summary of values of the environemtal variables can be found in Table 10.

3.4.1 Water availability.

The availability of water to livestock depends to a great extent on the levels of precipitation which, by definition, varies between Zones. A wealth of information about rainfall is available from the published literature, and so need not be detailed here. In summary, however, mean annual rainfall varies from some 150mm to 300mm in the Arid Zone sites, rising to 500-600mm in the Semi-arid sites in Mali, and 800-1000mm over those in Nigeria. In the Sub-Humid Zone, rainfall reaches 1250-1500mm in the central and eastern sectors of Nigeria respectively, while in the Highland areas the Jos Plateau receives around 1250 mm and the Mambilla Plateau some 2000 mm.

Rainfall does not necessarily reflect water availability, especially if, as in the Mali Delta which lies on the border between the Arid and Semi-Arid Zones, where extensive flooding takes place at the end of the wet season which persists well into the dry season, or if water is extracted from wells and boreholes, or artificially impounded. Thus two complimentary measures were recorded during aerial survey or obtained from published maps and ground surveys. These were: the visible presence or absence of surface water,streams and rivers sufficiently large to be usable by livestock; and, in the Arid and Semi-Arid Zones, the presence of various types of wells and boreholes. In the following paragraphs, these two measuremnts have been amalgamated to give the percentage of grids that were without water.

This percentage ranged from 0-70 during the wet season, and 8-92 in the dry season. During the wet season the driest area was the Mali Delta survey region taken as a whole, where 60% of the grid cells had no surface water, most of which were in the 'franges ouest' or the 'zone exondee' on the eastern and western margins of the survey site. The wettest region during the wet season was southern Gongola, where water was evident in every grid. In contrast only half of the survey grids were wet in the Arid Zone sites during the wet season.

In the dry season, the proportion of dry grids in the Arid Zone sites rises to between 83 and 90 percent, as the only water available is from wells and boreholes. A similar figure was estimated for the Grazing Reserve Sites in eastern Nigeria. The dry season figures for both the Mali Delta and Niono were very similar to those found in the wet season, indeed, slightly fewer grids in the Delta were dry in the dry season. The lowland parts of the Nigerian Sub-Humid zone contained an average of 60-65% waterless grids at this time of year, though the range within the central Case Study areas was 33 to 88%, Ganawuri being the wettest, and Kurmin Biri, Giwa-NAPRI and Funa Funa being the driest. The Highlands were well watered throughout the year, as only 8% of the grid squares were dry in March.

An alternative measure of water availability that can be calculated is the distance of a grid cell from a source. This has been investigated in some depth in Niger and in selected sites in the Nigerian Sub-Humid Zone.

In the Niger Pastoral Zone, the average distance from any grid cell to deep cement lined wells, deep unlined wells, shallow wells and boreholes was 12, 18, 32, and 45 kilometers, respectively. This would indicate that most areas are within trekking range of cattle, requiring to be watered every two days or so, which in turn suggests that the presence or amount of water in a well is of more importance than the distance or travelling time needed to reach them.

In the Sub-Humid Zone, the occurence of wells and boreholes was not recorded. and thus distance to water reflects rather the abundance and dispersion of pools, lakes, streams and rivers. In southern Gongola, even during the dry season, no grid was further than 15 kilometers from some sort of open water, and the median distance was considerably less, at some 3 kilometers. Again, as in the Niger survey site, this is well within a days' travelling for stockowners and their cattle. This compares with the Arid Gourma region of Mali, where, during the dry season, less than 8% of the grid cells contained open water, this figure being less than 2% if the river Niger was excluded. Thus in the Gourma region a high proportion of cells were further than 30km from a source of water.

3.4.2 Grass Cover and Greenness.

The degree of grass cover within a survey site was estimated in precisely the same way as was the percentage of cultivated land. It was measured in most, but not all sites, depending largely on the specific requirements of each survey. Where it was not estimated specifiaclly, it has, if possible, been calculated from vegetation type and the proportion of open grassland, considered in more detail in section 3.4.3, below.

Intuition would suggest that grass cover should be least in the northern Zones, and should be markedly less in the dry season than in the wet season. The result collected in the manner described in the preceding paragraph do not show these trends. Regardless of geographical location, the proportion of land covered with grass generally ranges between 15% and 25%. In two sites it was found to be rather higher than this level: in the ILCA Case Study Areas of central Sub-Humid Nigeria (49%), and, not surprisingly, in the high grasslands of the Mambila Plateau (57-66%). In two other sites it was found to be somewhat lower than the general level: in the heavily forested areas of lowland Gongola (7-11%), and in the nearby Grazing Reserve Sites to its north (4-5%). There is also no evidence of any substantial seasonal change within individual sites, irrespective of location, except in the Mali Delta, where dry season grass cover is some 50% higher than that seen in the wet season, at some 32%. Some evidence of change within the dry season is, however, apparent in those sites where several dry season surveys were conducted. Notable was the Niger Pastoral Zone, where late dry season grass cover was estimated at 15% compared with 26% early in the following dry season. Grass cover thus declines only slowly as the land becomes progressively more arid, until the end of the dry season, when it drops shrarply.

Here it is worth considering some of the factors which may determine grass coverage in a specific area. It will be reduced in areas where edaphic contraints prevent growth, or where grass is replaced competitively by shrubs and trees. As a result, the distribution of pasture grasses are likely to be patchy, even if the overall levels are similar between sites. This is, indeed, shown to be the case by the aerial survey measurements.

The Gourma region of Mali provides a good example of this phenomenon. During the 1984 wet season, grass was largely absent from the swath of land within 40-50 kilometers of the river Niger which forms the northern and eastern boundary of the surveyed area. The available grass was thus concentrated in the central, southern and western sectors of the region. In the preceding dry season, a substantial amount of grass was seen in the eastern and southern quadrants, while the north and western ones were largely bare. Similarly, within the Niger Pastoral Zone, in the Tchin Tabaradene Herders Association Area, grass cover was widespread in the wet season, but was both limited and very localised in the dry season.

The grass greeness was estimated in the Arid Zone Sites, based on an observed ranking scale from 0 to 5 within each grid, the smaller the number, the more yellow the grass. In, general it was found that the higher the percentage grass cover, the greener the grass, suggesting that more also means better as far as grass is concerned.

In addition to these visual estimations of pasture quality, it is also possible to assess greeness through using a radiometer or 'green machine' from which various indeces of vegetation cover can be obtained. One such index is the "Normalised Difference Vegetation Index" (NDVI), based of the reflectance of vegetation in the red and infra-red bands. The reliability and usefulness of this measure, as a means of assessing green biomass production and development of a drought early warning system is currently under investigation by ILCA in Mali and Niger, as well as in in Ethiopia and Kenya.

3.4.3 Vegetation Type and Tree Density.

The overall pattern of natural vegetation has been generally well documented and mapped. However, with the expansion of cultivation and the widespread process of deforestation taking place in the West African environment, natural patterns are gradually being modified. Interpretation of satellite imagery and the use of Side Looking Airborne Radar has provided a means of local updating but, despite this, the calibre of the available data is rarely sufficiently detailed to extract reliable infromation concerning the vegetation type or density for each survey grid cell that could then be compared to the livestock densities recorded.

Thus, a number of vegetation type categories were recorded in each grid surveyed as the percentage they occupied of each cell. The major categories in the Sub-Humid Zone sites were: closed canopy forest; open canopy forest; savanna woodland; and open grassland. In the Arid and Semi-Arid sites, savanna woodland was subdivided into dense and light woodland, and shrub/bush land.

To describe the details of the results collected would be a lenghty process, which may not be particularly informative because the distributions of the individual vegetation types are often very complex, interwoven and patchy.

In order to simplify the comparison of vegetation stucture between sites and Zones, a composite 'Vegetation Density Index' has been calculated where possible. This index runs from 0 to 500, corresponding to open ground and closed canopy forest respectively, and is based on the summed weighted proportions of each of the major vegetation types within each grid. Values for the site means ranged from 50-60 in the arid north and the high grasslands of Nigeria, to 190 in the Gongola lowlands. For the Malian areas the estimated VDI was 70-80, and for the Nigerian Case Study Sites it was approximately 130.

Given that a VDI of 167 represents dense savannah woodland the geographical variation in vegetation density implied by this index suggests that in the lowland sites average vegetation density increases progressively from very lightly wooded land in the north to heavily wooded savanna in the south. This is precisely what might be expected, and so confirms that the concept of a single index describing vegetation structure is valid.

Sufficient data to permit detailed comparisons on Vegetation Density Indeces between sites within a single ecological Zones are only available from the Nigerian (Sub-Humid) localities. As might be expected, the calculated VDI varied widely from one place to another. Much of southern Gongola, particularly the south, was densely forested, and the majority of the remainder was wooded to a greater or lesser extent. As intimated above, only the upland plateaux in the extreme south, and the floodplains alongside the major rivers were predominantly open grassland. Within the Case Study Areas in central Nigeria, three sites were largely grassland or lightly wooded savanna (Ganawuri, Abet Pambeguwa), three were mostly lightly wooded savanna (Tegina, Mariga and Funa Funa), and two - Kurmin Biri and Lafia - were rather more heavily wooded.

The relevance of vegetation structure to livestock densities differs according to Zone. In the drier regions, for example, open treeless terrain represents either grassland of variable quality, or bare ground. In the Sub-Humid Zone, by contrast, open ground implies grassland. At the other end of the scale, increasing arborescence reflects a potentially high risk of tsetse fly in the south, while there are no such attendant correlates of dense vegetation in the north.

In the more lightly wooded areas, it has also proved possible to estimate tree density in terms of the number of trees per hectare. In the Niger Pastoral Zone, for example, overall tree density was calculated to be about 2.5 trees per hectare. There was a substantial variation within the survey region, being lowest (at 0.18) in the Northern Ighazer Flood Plains, rising to 6 in the Tahoua Uplands. In general terms, tree density declined to the north, from a maximum of 10 per hectare (1000 per square kilometer) in the south east, to 1-5 per square kilometer in the north.

In the Delta, mean tree density was estimated at 9 per hectare, though only 1 tree per hectare was estimated for the 'delta vif'. Outside it, however, values reached 19 per hectare, or approximately 1 every 500 square meters, in the 'Zone Exondees'.

In the Niger Pastoral Zone, the abundance of a particular tree species was recorded - that of <u>Calotropis procera</u> - because its presence was considered to be a possible indicator of rangeland disturbance and deterioration. Though this species was found virtually throughout the entire survey Zone, it was found to be common only in the Sand-Dune Grasslands and Tahoua Uplands in the south and west of the site. This corresponds broadly with the central focus of livestock distributions.

3.5 LIVESTOCK, CULTIVATION, HUMAN AND ENVIRONMENTAL INTERREALTIONSHIPS.

3.5.1 Information Available from ILCA and RIM Reports.

Throughout the ILCA and RIM surveys, considerable efforts have been made to identify the land use and environmental parameters which are most closely associated with the distribution and abundance of livestock, cultivation and human habitation. Hence the choice of the systematic unstratified sampling strategy based on geographically precise grids which allows for the addition of any spatially defined data to the aerial survey database, either before, during or after the survey has been flown.

The variables which have consistently been examined in relation to livestock densities have been those descriptive of water availability; vegetation type and density; grass cover; cultivation levels; and habitation density. This is not to say that the same descriptors within each category have been used in each survey - distance to wells, for example, is a good indicator of water avaialability in the Gourma region of Mali, but is not in southern Gongola. The actual measures considered can be seen in Table 11.

3.5.1.1 The Arid Zone

In Niger, interrelationships were identified using multiple stepwise regression techniques. The survey site was divided into four areas for these purposes, - the northern floodplains, the central savannahs, the Tahoua uplands, and the sand-dune grasslands. Depending on stratum and season, the primary predictors of overall cattle numbers included measures of habitation, cultivation, vegetation and water availability.

In the 'Flood Plains', high cattle densities were most closely related to high percentage grass cover, but also were found during the late dry season in areas far from villages. At this time, Bororo cattle were particularly closely associated to grass cover, whereas high Azawak densities were better correlated with water availabilty, as represented by distance to fourages or puissards. In the early dry season, the cattle distributions were also related to vegetation density, being found in areas with more scrubland, though the Azawak breed more generally avoided open ground and were concentrated in localities with high tree density.

In the Central Savannas, during the late dry season, overall cattle numbers were closely associated with the higher cultivation levels, though grass cover and distance to fourages and cement well were also important. As in the Flood plains, grass cover was especially important to the Bororo cattle breed, which also appeared to avoid intense cultivation. Azawak cattle, on the other hand, were more closely related to cultivated land. This general pattern was also found in the early dry season.

In the Sand-dune Grasslands, late dry season cattle distributions were related primarily to water availability, and cultivation, whereas in the early dry season, in October, grass cover was again the most important general determinant of overall cattle densities. In the Tahoua Uplands, the largest late dry season cattle populations were also found in areas with abundant grass cover, and the Azawak were found to avoid areas of denser vegetation. This was not the case in the early dry season, where cattle were concentrated away from areas of open terrain, and in areas with high cultivation.

TABLE 11 DATASET USED FOR REGRESSION ANALYSES

Survey No.	Site	Season	%grass	VDI	%Cult	% Dry Grids	Ann Rain	Tsetse Indeces GP	GT	Total	Densities per square km TLU	Cattle	Shoats	Camels	Equines	Arab	Past	TLU/ Past	Catt/ Past	%TLU= Catt
ARID ZONE																				
Niger																				
1	NRL	LD	15.0	52.6	3.3	89.6	250	0	0	0	4.4	3.5	9.6	0.9	0.2	-	0.50	8.7	7.0	56
2		ED	26.0	52.6	3.3	90.0	250	0	0	0	5.8	4.6	14.1	1.1	0.2	-	0.44	13.2	10.5	56
3		LW	25.8	56.2	3.3	46.4	250	0	0	0	5.9	4.1	10.2	1.9	0.3	-	0.49	12.0	8.4	49
4	TTZone	D	8.3	84.0	1.1	92.0	250	0	0	0	5.1	4.8	8.1	0.8	0.2	-	0.56	9.1	8.6	66
5		W	42.2	84.0	1.8	43.0	250	0	0	0	6.9	6.9	15.2	0.5	0.2	-	0.95	7.3	7.3	70
Mali																				
6	Gourma	ED	21.5	71.7	2.0	83.0	300	0	0	0	4.2	4.8	7.1	0.05	0.05	0.4	0.31	13.7	15.6	80
7		LD	19.2	71.7	2.0	83.0	300	0	0	0	3.8	4.3	7.0	0.05	0.05	0.4	0.36	10.5	11.9	79
8		W	17.6	71.7	2.5	48.9	300	0	0	0	5.6	5.7	14.0	0.05	0.05	0.4	0.38	14.7	15.0	72
SEMI ARID ZONE																				
Mali																				
9	Delta	ED	-	81.5	22.6	54.6	550	26	15	41	16.5	22.5	7.1	0	0.05	-	-	-	-	96
10		LD	32.0	81.5	22.6	60.0	550	26	15	41	24.9	33.8	12.7	0	0.05	-	0.59	42.4	56.3	95
11		EW	23.0	81.5	22.6	60.0	550	26	15	41	17.4	22.5	16.0	0	0.05	-	0.30	52.7	68.2	91
12	Niono	D	32.9	-	23.3	70.0	550	26	15	41	10.4	11.8	20.7	0.8	0.05	-	0.55	18.8	21.3	79
13		W	-	-	23.3	70.0	550	26	15	41	15.6	19.6	18.6	0.05	0.05	-	0.70	22.6	28.4	88
14	Delta Zones	D	53.5	83.5	18.1	37.7	550	26	15	41	23.7	31.9	14.8	0	0.05	-	0.73	28.4	37.7	87
15		D	30.8	83.5	18.1	31.3	550	26	15	41	23.2	31.9	16.3	0	o.05	-	0.64	27.3	42.1	90
16		D	57.3	83.5	18.1	25.0	550	26	15	41	10.6	14.1	9.2	0	0.05	-	0.44	25.2	34.1	95
Nigeria																				
17	Bauchi	MW	-	-	17.0	-	1000	446	158	604						19.3	0.60			
18	NLPU Res'ves	D	-	169.1	8.4	92.0	1000	446	158	604	5.6	6.5	5.3	0	0.05	13.1	0.94	6.0	6.9	81
19		W	4.4	169.1	8.4	-	1000	446	158	604	8.7	11.0	2.4	0	0.05	13.1	1.14	8.5	7.8	81
SUB-HUMID ZONE																				
Nigeria																				
20	Case Study	D	-	130.0	17.5	64.0	1250	1280	446	1721	15.8	18.3	2.4	0	0.05	14.0	1.28	10.2	14.3	80
21		W	49.3	130.0	17.5	-	1250	1280	446	1721	18.7	21.8	2.8	0	0.05	14.0	1.44	9.9	15.1	80
22	Gongola Low'	D	7.3	187.9	5.5	62	1500	994	226	1176	9.8	11.0	1.2	0	0.05	10.5	0.30	32.6	36.2	79
23		W	11.5	187.9	5.5	0	1500	994	226	1176	8.9	9.7	1.1	0	0.05	10.5	0.39	22.8	24.9	79
HIGHLANDS																				
Nigeria																				
24	Jos Plateau	D	-	-	-	-	1250	0	0	0	12.8	16.4	-	-	-	-	-	-	-	90
25		W	-	-	-	-	1250	0	0	0	36.4	46.8	-	-	-	-	-	-	-	90
26	Mambila Pl	D	66.3	60.0	6.2	8	2000	0	0	0	25.6	33.3	2.6	0	0.1	23.3	0.99	23.8	32.4	91
27		W	57.5	60.0	6.2	0	2000	0	0	0	44.0	59.9	2.6	0	0.1	23.3	1.85	23.78	32.4	91

NB Total TLU figures and % contributed by cattle incorporate arable farmers goats. Pastoralist Habitations exclude Agropastoralists.

In summary, depending to some extent on season and stratum, the distribution of cattle in the NRL was most often determined by the amount of grass available, and to a lesser extent by the levels of cultivation and the density of the vegetation. The more extensive grass cover was generally associated with high cattle densities, especially of the Bororo cattle and particularly in the Central Savannas, but intense cultivation and thick vegetation was either apparently avoided or sought after, depending on location, breed and season. Water availability appeared to be rarely of primary importance, and indeed, in the Sand-Dune grasslands, the cattle were generally found in areas furthest from wells.

In the Gourma region of Mali little detailed analysis has yet been performed, but outstanding during the wet season is the correspondence between the distribution of cattle with those of surface water, grass cover and, to a lesser extent, light savanna woodland. During the dry season, these apparent relationships are less clear. Also striking is the fact that the cattle seem to avoid the Niger River during the wet season, and be more closely associated with it in the dry season.

There is therefore and apparent contrast between the two Arid Zone sites:- in Niger, pasture availability is the most frequent correlate of high cattle densities, but is tempered by cultivation levels, vegetation density and water availability; in the Gourma, water is likely to be the overriding constraint upon livestock distributions, modified by grass cover and vegetation density, but seemingly unrelated to cultivation patterns.

3.5.1.2 The Inland Delta of Mali.

In the surveys of the Mali Delta, emphasis was placed on the collection of information describing the levels of human habitation and cultivation, in addition to recording parameters relevant to water availability and vegetation.

The cattle of this region were associated primarily with villages only in the early dry season. In the 'Zones Exondees' to east and west of the actual delta, more cattle were found near villages, though in the High Plains to the south and east, the reverse was the case.

Cultivation levels were more generally important in determining cattle distribution patterns than they were in the Arid Zone, though depending to a great extent on the size of the grazing units in which the cattle were managed. If in small groups, cattle numbers were consistently correlated primarily with crops as represented by either total cultivation percentage, the amount of rice or the levels of millet cropping.

Only in the middle of the dry season was the density of cattle in large grazing units commonly associated with the levels of arable farming. At other times of the year, it was the natural environmental parameters which were more likely to most influence the densities of such cattle. In June, water availability, as shown by the frequency of surface pools and rivers, was the primary correlate of the number of these animals in all strata except the western transition zone (or 'franges ouest'), where its place was taken by the proportion of open savanna ('savane herbacee'). In two strata - the western transition zone and the flooded plains - environmental parameters were also most closely related to the numbers of cattle in large herds during the early dry season. In the former, they were concentrated in areas of high tree density, whilst in the latter, they avoided the more flooded grid cells.

It will be apparent from the preceding paragraphs that the percentage of grass cover was never found to be an important correlate of cattle densities in any part of the Mali Delta, as it was in the Arid Zone survey sites. Further the importance of cultivation, and to a lesser extent, human habitation levels often outweighed that of vegetation density or water availability. This is in direct contrast to the situation described for both the Gourma and the NRL, and must primarily reflect the relative lack of the arable farming found in these sites, as well as the comparative severity of the environmental constraints that operate there.

3.5.1.3 The Sub-Humid Zone and the Highlands.

A discussion of the separate relationships between cattle densities and both land use and environmental parameters is presented at some length in RIM (1985), and so will not be reiterated here. Rather, this section will briefly describe the results of the multivariate analyses presented in that report.

In both wet and dry seasons, the most important single predictor of cattle densities, in the Sub-Humid Zone as a whole, is the proportion of grids that are without water in the dry season. In a stepwise regression of the dry season figures, vegetation density (as represented by the vegetation density index described in section 3.4) is identified as the second significant predictor, whilst in the wet season, none of the other variables, be they environmental or descriptive of human population levels, contributed further to the explanation of cattle density in the Zone.

If dry season water is forced out of the analysis, then it is vegetation density that is the most significant predictor of both dry and wet season cattle densities - decreasing vegetation density being associated with high cattle populations. Neither arable farmer habitation levels or cultivation percentage can be isolated as significant predictors of livestock densities, and indeed the partial correlation between cattle and cultivation level is actually negative, though not statistically significant. This reflects the complex relationships between the livestock and arable farming sectors, which will be discussed further below.

In the Case Study Areas alone, it is the numbers of arable farmer habitations that best predict cattle densities, rather than any of the environmental parameters. This is likely to be because the relationship between dry season water and cattle numbers was not significant in these sites. This, in turn may be due to a degree of underestimation of water availability in the northernmost study areas, as in these drier sites wells were not recorded but are likely to represent a substantial source of water.

Thus the correlation between arable habitation and cattle densities in central Nigeria may not reflect the true state of affairs, but certainly does suggest that the link between farming and cattle is closer in the central corridor than it is in the eastern parts of the country.

In order to compare these results from the Sub-Humid Zone with those from the other ecological Zones, it is first necessary to consider what the correlation of high cattle densities with abundant dry season water and low vegetation density actually reflects. It is unlikely that water availability per se is the major causal factor underlying patterns of cattle distribution in the SHZ, because much of it is well watered, particularly in the wet season. Similarly vegetation density itself may not be strictly relevant, but reflect other conditions, such as reducerd tsetse challenge and more widespread open grassland. It seems probable, therefore, that available water and open vegetation represent a third parameter that encourages the presence of cattle.

Where these conditions obtain, it is likely that the available grazing is widespread, of relatively high quality, and is present for a comparatively large part of the year.

Similarly, arable farmer habitations may, in fact, represent both markets for the pastoralists' produce and a source of the crop residues that the cattle need to supplement their dry season forage.

Thus, taking these two associations together, it seems probable that large scale variations in cattle distributions within the Sub-humid Zone of Nigeria are primarily determined by the avaiability of grazing, and thereafter, particularly in areas with high farming populations, by proximity to concentrations of arable dwellings and the cultivation and markets they represent.

If true, then this pattern of constraints on pastoralism in the Sub-Humid Zone is remarkably similar to the situation that can be inferred from the Arid and Semi-Arid Zone results described above. There too, the cattle population levels are primarily linked to environmental constraints related to grazing and water availability in those sites where arable farming is rare. In the Delta, as in the central SHZ, the farming population is comparatively high, and cattle numbers are more directly associated with those parameters that reflect cultivation levels and the availability of markets.

3.5.2 A Broad Scale Reanalysis of the Data.

As can be seen, similar environmental and land use parameters are related to livestock densities in all three ecological Zones, but the relationships are not constant in either form or direction, if examined in detail.

Much of this apparent inconsistency derives from the variety of measures and analysis techniques used, and more importantly from the local variability in conditions and constraints. Of more general relevance for valid comparisons across the range of West African ecosystems would be a set of measures which could be applied to all the areas surveyed, so that every point could be compared, and all regions plotted on the same axis. In this way, it may be possible to make some generally valid statements about the factors which are significantly associated with observed trends in livestock abundance, and which can be applied to all areas within the three ecological Zones that the present report considers.

3.5.2.1 The Data Used

The dependent variables considered were total TLU densities, total cattle densities, grazing unit size, and pastoral habitation density. The independent parameters examined as possible predictors of these dependent variables were vegetation density, proportion of grids without water during both wet and dry seasons, percentage cultivation, human habitaion densities, annual rainfall, percentage grass cover, and finally, a measure of tsetse abundance.

All except the last of these measuements have been taken directly, or derived from the reports of the relevant surveys. Some were not specifically estimated in all Zones, and where this was the case, the figures have been derived from a comparable measure. An example of such an instance is percentage grass cover, which, in several of the Sub-Humid Zone sites has been calculated from the estimates of the proportion of open grassland within each grid.

The tsetse fly densities were assembled using two relationships:- between annual rainfall and trapping frequency (Rogers, 1985); and between trapping frequency and population density (Bourn, 1983). Figures for two species were available, a dry savanna species (_Glossina tachinoides_) and a riverine species (_Glossina palpalis_). These have been combined to give an index of overall tsetse density, which is considered to be valid, despite the fact that figures for the most infectious species (_G. morsitans_) were not available. This index has been adjusted for known absence of flies at high altitudes.

If neither direct nor indirect estimates could be extracted from the aerial survey data, for example, vegetation density in Niono, then no attempt was made to use alternative sources of data, such as published SLAR maps, as no assumption of comparability was likely to be valid.

3.5.2.2 The Analytical Techniques Employed.

The analysis was performed using both bivariate and multivariate stepwise regression (Sokal and Rohlf, 1981; Marriott, 1974) and performed on a PDP11 computer equipped with BMDP statistical software. The data from each zone was amalgamated into groups where the size of individual survey sites was small. For each site or group of sites a mean value for each parameter was calculated, for each season or sub-season sampled, and it was these means that were used in the regressions.

Some data is missing from this set - for example the vegetation data from Jos and Niono. For this reason, multiple stepwise regressions were performed on what amounts to a subset of the data, i.e. the sites for which all the relevant parameters were known. The bivariate analyses were also calculated for all sites possible, but as only two variables per analysis were involved, then the number of cases with missing values is small.

The values used are presented in Tables 11.

3.5.2.3 The Broadscale Interrelationships Identified.

It should be emphasised at this point that any relationships identified in this section as statistically significant, by definition, hold across the entire range of survey sites from Arid to Highland. If there is no significant relationship, then this does not preclude the possibility that within a particular Zone, or within a specific survey area, a relationship between the relevant paramaters is statistically significant. Thus trends described below are likely to relate to large scale variations of livestock numbers across the whole of that part of West Africa which supports livestock. The fact that such trends can be found, given the enormous ecological variability encompassed by the surveys, suggests that the paramters identified as predictors of livestock densities are fundamental to their distribution.

3.5.2.3.1 Bivariate Analyses

These analyses have been performed at three levels:- incorporating both wet and dry season figures to give an indication of the general strength (or otherwise) of the correlations; and then for wet and dry season densities separately, so as to identify any contrasts in the relationships that there might be at different times of the year. The numerical results are summarised in Table 12, and displayed graphically in Figures 8 and 9.

TABLE 12. SIGNIFICANCE LEVEL AND CORRELATION COEFFICIENT OF RELATIONSHIPS IDENTIFIED FROM BIVARIATE REGRESSION ANALYSES.

INDEPENDENT VARIABLE	DEPENDENT VARIABLE (All densities per square kilometer)							
	TLU		CATTLE		SHOAT*		PASTORALIST HAB	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
% Dry Grids	003 -0.80	001 -0.95	0003 -0.81	0001 -0.94	NS	NS	03 -0.66	NS
Veget'n Density	NS	NS	NS	NS	05 -0.56	NS	NS	NS
Veget'n Density (ex Arid)	02 -0.89	07 -0.84	01 -0.92	07 -0.84	NS	NS	NS	NS
% Grass Cover	02 0.66	06 0.69	02 0.69	08 0.64	NS	NS	01 0.74	06 0.69
% Cult'n	01 0.63	NS	01 0.64	NS	NS	NS	NS	NS
Annual Rainfall	10 0.42	02 0.71	NS	02 0.72	NS	NS	NS	06 0.65
Past'st Habit'n	10 0.45	03 0.70	NS	04 0.70	NS	NS		

* Excluding Arable farmers goats

1 Total TLU and Cattle Densities: Water Availability.

Two measures of water availability have been used in the present analysis - annual rainfall and the proportion of grid cells with neither surface water nor wells of any kind.

If the figures from both wet and dry seasons are considered together, then there is a positive relationship, as might be expected, between cattle densities and annual rainfall levels ($p<0.03$) - i.e the wetter the area, the more cattle are found in it, on a year round basis.

If, however, seasonal densities of livestock are examined separately, then this seemingly straightforward relationship breaks down. Annual rainfall is not significantly linked to either cattle or TLU densities during the dry season. This partly reflects the high densities of livestock found in the Mali Delta during the dry season, despite its low rainfall, and partly the fact that, within the Sub-Humid Zone, cattle densities tend to fall with increasing rainfall as reported by Bourn and Milligan (1983).

Coe et al (1976), however, demostrate that at relatively low rainfall levels, - below 700-800 mm/year - livestock biomass in East Africa rises with precipitation. Thus the large scale variation in livestock desnites with rainfall levels takes the form of an inverted U with a peak at some 1000-1100 mm/year. This has been documented by Bell (1982) and East (1984), and probably reflects the fact that in very wet areas, the dominant vegetation is sufficiently thick to preclude the growth of grass, whereas in drier areas, increased rainfall is likely to enhance both the quality and quantity of available grazing.

During the wet season, in contrast, both total livestock and cattle densities are strongly and positively correlated to annual rainfall levels ($p< 0.02$).

The links between rainfall levels and livestock densities are thus rather complex, and do not readily lend themselves to regression analyses. As well as the factors outlined above, this reflects the fact that rainfall does not necessarily correlate with water availability. This is due to regional variations in runoff, evapotranspiration, water retention and flooding patterns and so on.

The use of the number of grids without water as a measure of its availability circumvents some of these complications. This measure is the strongest of all the correlates of cattle and TLU densities both on an annual basis ($p < 0.00001$, $r = 0.888$) and during the dry season ($p<0.001$), when it explains some 63% of the observed variation. The relationship is strongly negative.

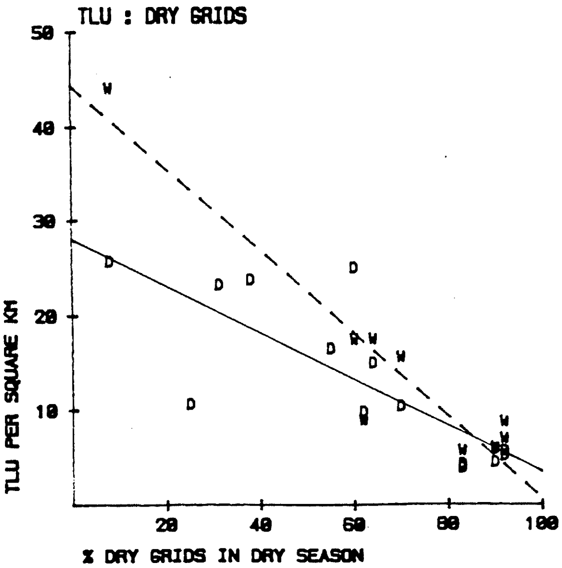
Livestock are thus found, during the dry season, primarily where water is most readily available on the ground. Perhaps surprisingly, this relationship is reversed during the wet season, but is significant at only the 6% level. This suggests that even the least well watered areas are capable of supporting cattle during the wet season, and indeed are used preferentially by the pastoralists, thus reserving the wetter regions for use during the dry season.

A further very striking result of these analyses is that the avialability of dry season water is a better predictor ($r = 0.94$, $p<0.0005$) of wet season cattle and TLU densities than it is of their dry season densities. Given that livestock are concentrated in the drier areas during the wet season, this link with dry season water is unlikely to represent an attraction to water itself,

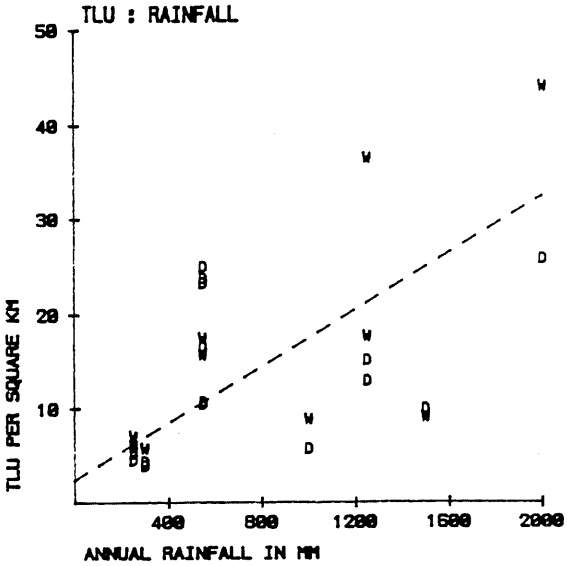
FIGURE 8

BIVARIATE ANALYSES : TLU

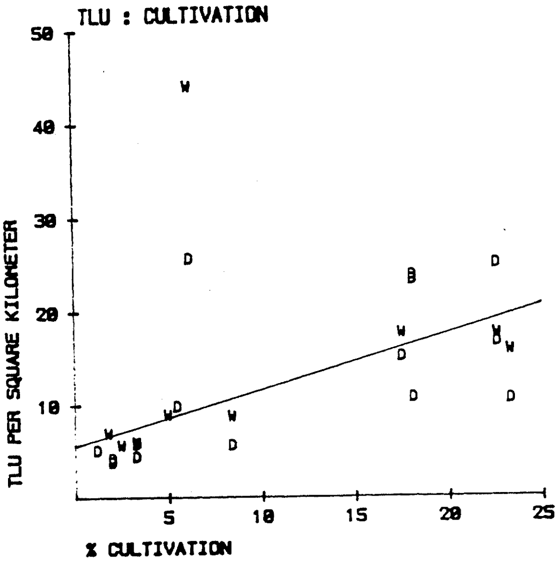
W = WET SEASON (_ _ _)　　D = DRY SEASON (____)



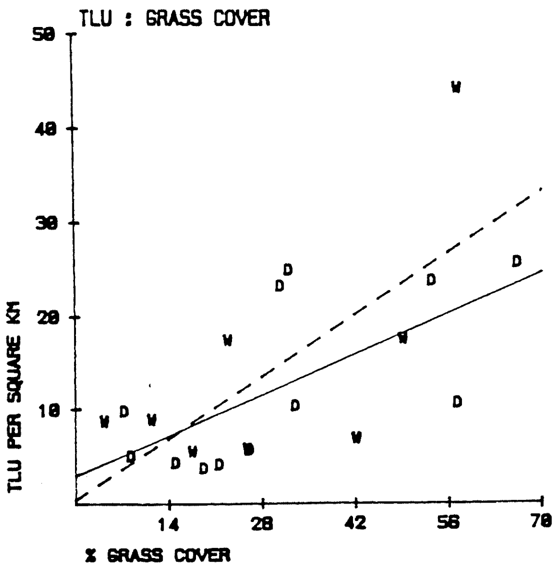
WET SEASON: Y = 44.3 - 0.435X　R = 0.95　P:0.001
DRY SEASON: Y = 28.0 - 0.246X　R = 0.80　P:0.0003



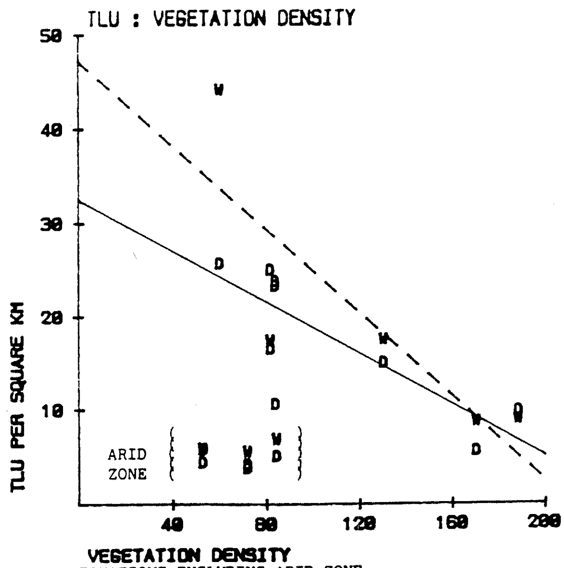
WET SEASON: Y = 2.51 + 0.015X　R = 0.71　P:0.021
DRY SEASON:　Not Significant



WET SEASON: Not Significant
DRY SEASON: Y = 5.6 + 0.6X　R = 0.63　P: 0.012



WET SEASON: Y = 0.51 + 0.47X　R = 0.68　P: 0.06
DRY SEASON: Y = 3.08 + 0.31X　R = 0.66　P: 0.02

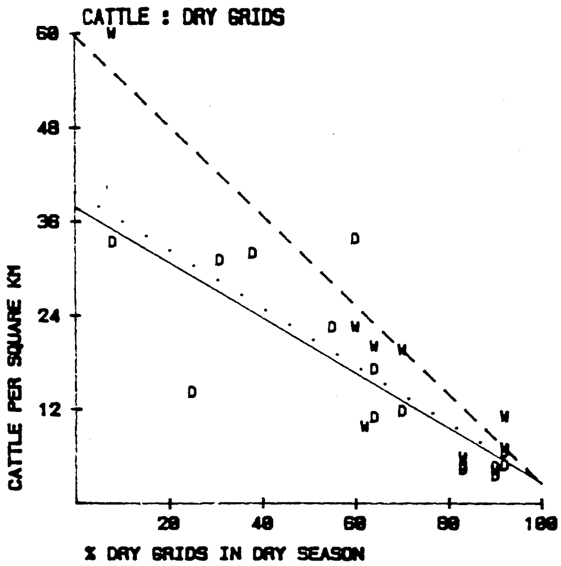


EQUATIONS EXCLUDING ARID ZONE
WET SEASON: Y = 47.2 - 0.22X　R = 0.84　P: 0.06
DRY SEASON: Y = 32.5 - 0.14X　R = 0.90　P: 0.05

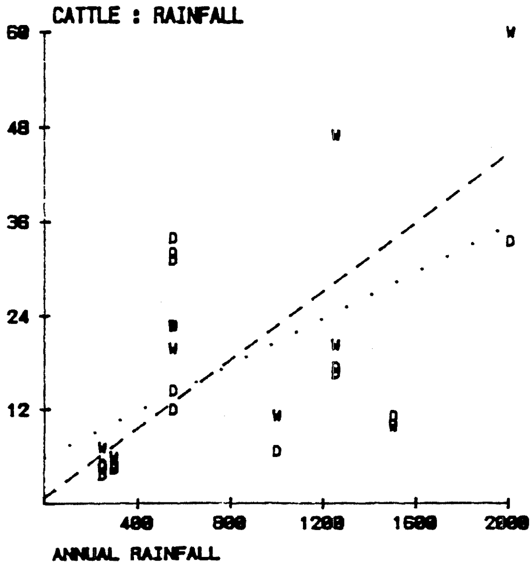
FIGURE 9

BIVARIATE ANALYSES : CATTLE

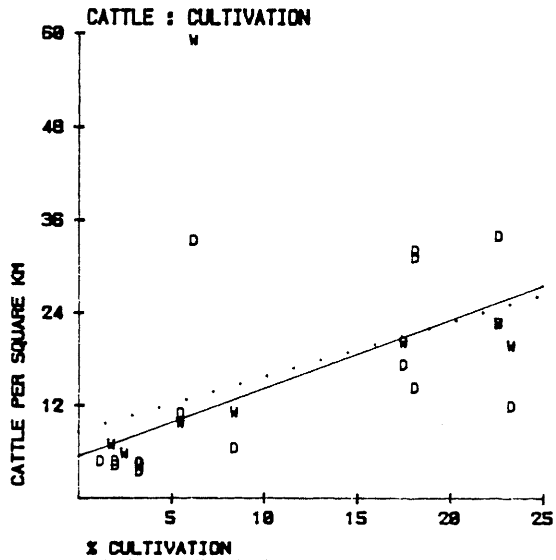
W = WET SEASON (_ _ _)   D = DRY SEASON (____)   (. . . .) = ANNUAL



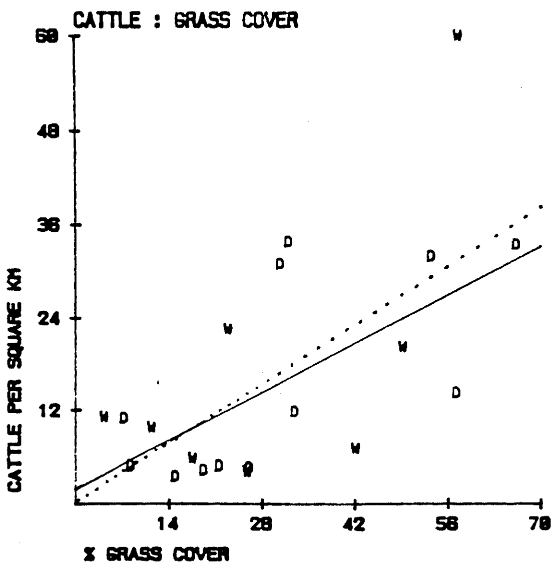
ANNUAL: Y = 39.8 - 0.35X R = 0.81 P:0.0003
WET SEASON: Y = 59.9 - 0.61X R = 0.94 P:0.001
DRY SEASON: Y = 39.8 - 0.37X R = 0.79 P:0.0001



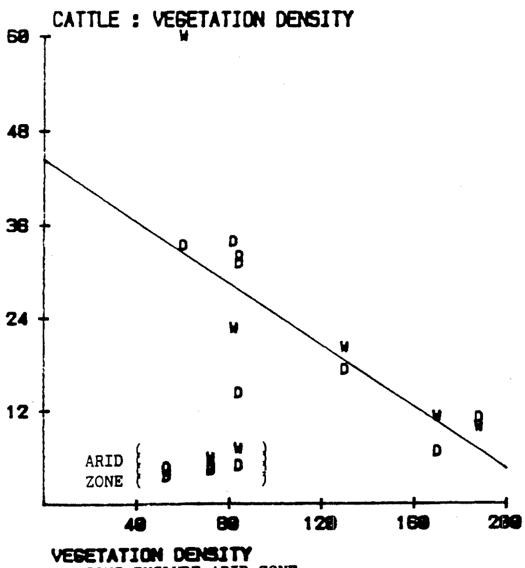
ANNUAL: Y = 5.81 + 0.015X R = 0.75 P:0.003
WET SEASON: Y = 0.79 + 0.22X R = 0.72 P:0.018
DRY SEASON: Not Significant



ANNUAL: Y = 8.77 + 0.70X R = 0.66 P:0.035
WET SEASON: Not Significant
DRY SEASON: Y = 5.64 + 0.87X R = 0.64 P:0.01



ANNUAL: Y = 0.34 + 0.54X R = 0.66 P:0.002
WET SEASON: Not Significant
DRY SEASON: Y = 1.97 + 0.45X R = 0.67 P:0.018



EQUATIONS EXCLUDE ARID ZONE
WET SEASON: Not Significant
DRY SEASON: Y = 44.27 - 0.20X R = 0.92 P:0.01

but rather reflect the enhanced pasture quality of areas which are well watered in the dry season (see section 3.5.1.2 above).

2. Total TLU and Cattle Densities: Cultivation and Arable Habitation

In the dry season, there is a highly significant postitive relationship ($p < 0.001$) between both cattle and TLU densities and cultivation levels - animals are found in larger numbers where there is more cultivation. This relationship holds, though less strongly ($p < 0.04$) if both wet and dry season densities are considered together, but does not during the wet season, when there appears to be no statistical link between animal and cropping levels.

This fits well with long held ideas that there is a general relationship between livestock population densities and cropping levels, but that it does not necessarily hold true throughout the year. Thus, cattle graze upon crop residues in the dry season, while uring the rains, these resources are neither available nor required as the natural pasture alone is sufficient, and can be found in remote areas far from human population centres.

While true in the broad sense, this is undoubtedly an oversimplification, as shown by the fact that, within the Sub-Humid Zone, cultivation percentage and cattle densities are related during the wet season only in the central corridor sites of Nigeria, and not at all during the dry season. This reflects several phenomena. Firstly, cattle are kept in large numbers close to, rather than actually inside, areas with intense cultivation, so as to avoid excessive trampling. Also, the cattle are only reliant on residues between harvesting and the first appearance of newly flushing grass. These two factors alone would tend to obscure a simple correlation between the aerial survey data.

Further, some types of cropping, such as yam growing, do not produce residues which the cattle can use, and are especially vulnerable to trampling. Such variability in crop types is not reflected in the overall measure of cultivation that is taken from the air. A final factor is that, in some areas, the pastoralists may be actively avoid cultivated areas. Two such examples are the yam growing areas and the high grasslands of southern Gongola State, where there is intense conflict between the arable and pastoral sectors.

In relation to the arable farmer habitations with which cultivation is associated, there is unfortunately insufficient data to permit regression analyses across all three zones. Within the Sub-Humid Zone, however, cattle densities were positively correlated to arable dwelling densities, though the relationship was statistically significant, even if rather weak. Cattle were also found in larger numbers near towns of significant size, and near to major roads. Such parameters reflect these pastoralists' preference for areas which are both less remote and close to markets where cattle and cattle products can be sold, and where grain, veterinary supplies and manufactured products may be bought.

3. Total TLU and Cattle Densities: Grass Cover and Vegetation Density.

Percentage grass cover is postively and significantly related to both cattle and TLU densities on an annual basis, and during the dry season ($p < 0.02$). This relationship also holds for the wet season, though the significance level is somewhat reduced ($0.08 > p < 0.06$). In other words, grass cover is an important factor in determining livestock distributions throughout the year, but more so in the dry than wet season. This stands to reason if, as is likely, grass is more freely available during the rains and so limits cattle movements only when it is dry.

There is no overall relationship between vegetation density and animal numbers either wet or dry season. This is because low vegetation cover does not represent the same conditions in all three ecological Zones. In the Semi-Arid and Sub-Humid Zones, low vegetation density implies a high proportion of open grassland, whilst in the Arid Zone, it often reflects bare ground or desert.

If the Arid Zone sites are therefore excluded, then vegetation density becomes a highly significant predictor of both cattle and TLU densities in the dry season ($p < 0.02$ and 0.01 respectively), and is associated with them, though not at the formally significant level ($p < 0.08$), during the wet season. Thus more animals are found in areas with relatively open vegetation, i.e those most likely to support a substantial grass cover, and least likely to contain tsetse species with the accompanying risk of trypanosomiasis.

This is not to say that dense forest is totally avoided by pastoralists. During the dry season, significant numbers of cattle were seen in the closed canopy forests of southern Gongola. These were largely the browse feeding Sokoto Gudali which had moved from their more usual haunts in the Semi-Arid Zone to the north, in response to the extant rinderpest epidemic.

3.5.2.3.2 Some implications of the relationships identified.

Five major environmental parameters have been identified as being of significant predictive value in estimating livestock densities across all three ecological Zones - dry season water availability, annual rainfall, cultivation levels, percentage grass cover, and in the southern Zones, vegetation density. For four of these variables it is possible to suggest optimum values which would maximise livestock populations. Thus water should be available in every grid during the dry season - i.e 0% dry grids; and 100% of both grass cover and open ground (i.e. a vegetation density index of zero) would maximise the avaialble grazing. The optimum levels of cultivation are likely to be in the region of 50%, given the fall in cattle densities in areas with more than 60% cropping that was recorded in Bourn and Milligan (1983).

If the regression equations identified in section 3.5.2.3.1 above are used to extrapolate predicted cattle and TLU densites at these optimum values, a striking consistency is evident (Table 13). Predicted maximum cattle densities range from 60-64 per square kilometr in the wet season and 38-50 in the dry season. Similarly, the equivalent TLU values are 44-47 and 28-35 per square kilometer in the dry and wet season respectively.

This consistency in the face of the wide disparity of the variables used, and the range of habitats covered by the aerial surveys, suggest that there is a fixed limit to the density of livestock that the land can support. It is tempting to suggest that this limit represents the natural maximum stocking levels of optimal quality, but unimproved, rangeland. If true, this is some 43 cattle per square kilometer in the dry season, rising to 61 per square kilometer in the wet season, corresponding to a year round value of approximately 52 per square kilometer or approximately 2 hectares per head.

TABLE 13 EXTRAPOLATED CATTLE AND TLU DENSITIES AT ASSUMED OPTIMAL LEVELS OF SIGNIFICANT SINGLE PREDICTORS.

PREDICTOR	CATTLE DENSITY		TLU DENSITY	
(OPTIMA)	WET	DRY	WET	DRY
Vegetation Density* (0)	63.88	44.2	47.24	32.48
% Grass Cover (100)	62.14	46.6	47.9@	33.98
% Cultivation (50)	NS	49.3	NS	35.8
Dry Grids (dry season) (0)	59.83	37.8	44.32	28.03

Figures are numbers per square kilometer
* Equation derived from data excluding Arid Zone
@ Significant at 6% level only

3.5.2.3.3 Bivariate Analysyes: Sheep and goats

Considering the pastoralists' sheep alone, i.e those counted from the air, only vegetation density correlates significantly with animal density, and then only in the wet season, when more sheep are associated with open vegetation.

If the small ruminants as a whole are considered, i.e inclusive of the arable farmers' goats in the Sub-Humid Zone, then annual rainfall is a strong predictor of their densities, explaining some 50% of the variance, but again only in the dry season, with high rainfall being associated with high populations. Pastoralist dwelling density also correlates with small ruminant densities during the dry season ($r = 0.62$, $p<0.05$).

3.5.2.3.4 Bivariate Analysis: Pastoralist Habitation.

The distribution of pastoralist dwellings is consistently related to percentage grass cover throughout the year, but most closely during the dry season ($p<0.01$), when grass is likely to be most limiting. Water availability is also a significant predictor of pastoralist habitation desnity in both seasons, - the proportion of dry grids in the dry season ($p<0.02$), and annual rainfall during the wet season - though in both cases, the significance levels are lower than for grass cover ($p<0.05$).

This suggests that pastoralists congregate primarily in areas with good grass cover but also with sufficient water. The cattle they herd, in contrast, have been shown to be concentrated primarily on land with abundant surface water, and less significantly in pasture with high percentage grass cover. This implies that the livestock owners build their dwellings in regions with the best pasture, and their cattle are able to survive on the outlying areas which may not support so much grass.

3.5.2.3.5 Multivariate Analyses.

The bivariate regression analyses discussed in the previous section serve well to identify links between livestock or human population levels and particular characteristics of the land they use. They do not however take into account the possible interrelationships between the independent variables that may enhance or disguise the true associations. Nor do they facilitate the process of identifying the most important predictors of livestock densities, if more than one independent variable is significantly related to the dependent one.

To do this it is necessary to examine the potentially predictive parameters together in a single process. This can either be done by creating a single variable which combines several measurments into one, as in the 'land suitability index', briefly mentioned above and described in more detail in section 4, or by performing multivariate analyses such as multiple stepwise regression.

Such regression analyses of the data from all the ecological Zones (summarized in Tables 14 and 15) shows unequivocally that the primary predictor of year round, wet and dry season cattle and TLU density is the proportion of grid cells that are dry during the dry season. The proportion of the variance explained by this single parameter is, for cattle and TLU respectively, 89% and 90% in the wet season, and 62% and 63% in the dry season.

The importance of the remaining parameters depends on season. During the rains, three other variables contribute significantly to increased TLU

TABLE 14 MULTIVARIATE ANALYSES: PRIMARY PREDICTORS IDENTIFIED BY STEPWISE REGRESSION.

Dependent Variable		Primary Predictor Parameter (Sign)	%Variance Explained	Significance Level
Densities per Square kilometer				
Cattle	Wet Season	Dry Grids (-ve)	89	****
	Dry Season	Dry Grids (-ve)	64	**
	Annual	Dry Grids (-ve)	70	***
TLU	Wet Season	Dry Grids (-ve)	90	****
	Dry Season	Dry Grids (-ve)	63	**
	Annual	Dry Grids (-ve)	70	***
Sheep & Goats (- arable goats)	Wet Season	Veg Density (-ve)	32	*
	Dry Season	None		
	Annual	Annual Rain (-ve)	50	***
Pastoralist Habitation	Wet Season	% Grass (+ve)	48	07
	Dry Season	% Grass (+ve)	55	**
	Annual	% Grass (+ve)	33	*

Significance levels: * = 5%, ** = 1%, *** = 0.1%, **** = 0.01%.

TABLE 15 MULTIPLE REGRESSION EQUATIONS INCORPORATING SIGNIFICANT PREDICTORS IN ORDER OF EXTRACTION FROM STEPWISE REGRESSION.

CATTLE DENSITIES				
	DRY	Y = 22.9 - 0.23DRYGD + 0.74CU	R = 0.88	P<0.04
	WET	Y = 42.3 - 0.49DRYGD + 13.4PAST - 0.87TSE	R = 0.98	P<0.02
CATTLE DENSITIES EXCLUDING DRY GRIDS				
	DRY	Y = 1.88 + 1.24CU + 0.10RAIN	R =0.90	P<0.02
	WET	Y = 16.8 + 0.03RAIN - 0.23VDI	R =0.95	P<0.02
TLU DENSITIES*				
	DRY	Y = 27.65 - 0.25DRYGD	R = 0.79	P<0.01
	WET	Y = 30.70 - 0.34DRYGD + 8.0PAST - 0.05TSE + 0.19CU	R = 0.999	P<0.01
TLU DENSITIES* EXCLUDING DRY GRIDS				
	DRY	Y = 0.19 + 0.34CU + 0.008RAIN	R = 0.88	P<0.04
	WET	Y = 14.4 + 0.20RAIN - 0.17VDI	R = 0.96	P<0.05
SHEEP AND GOATS**				
	WET	Y = 14.39 - 0.637VDI	R = 0.57	P<0.05
PASTORALIST HABITATION DENSITY				
	DRY	Y = 0.30 + 0.0078GR	R = 0.74	P<0.01
	WET	Y = 0.26 + 0.009GR	R = 0.69	P<0.07
TLU PER PASTORALIST HABITATION				
	DRY	Y = 1.66CU + 0.18RAIN + 0.27DRYGD -21.554	R = 0.985	P<0.01
CATTLE PER PASTORALIST HABITATION				
	DRY	Y = 6.40 + 2.03CU + 0.14RAIN	R = 0.954	P<0.01
PROPORTION OF TLU* WHICH ARE CATTLE				
	DRY	Y = 102.17 - 0.38DRYGD	R = 0.79	P<0.01

CU = percentage cultivation; DRYGD = % grids without water in the dry season;
RAIN = Annual Rainfall in mm; PAST = Pastoralist Habitation Density;
TSE = Tsetse Density Index; VDI = Vegetation Density Index;
GR = % Grass Cover.
* Including Arable Farmers Goats
** Excluding Arable Farmers Goats
Pastoralist Habitation is exclusive of Agropastoralists

densities - a rise in pastoralist numbers, then a fall in tsetse density, and finally a rise in cultivation levels. As far as cattle are concerned, then only changes in pastoralist numbers and tsetse densities add significantly to the predictive value of dry season water availability.

In the dry season, the only additional parameter that is significantly associated with the densities of livestock is the percentage of cultivation, though only for cattle and not TLU.

The total percentage of the large scale variation in cattle and TLU densities that is explained by these measures is 62% and 64% respectively in the dry season, and no less than 98.5% and 99.8% in the wet season. These figures are remarkably high considering the range of sites that have been included, which strongly suggests that the measures taken are of very considerable predictive value throughout West Africa. Though it is commonly thought to be unwise to infer causality from regression analyses, the temptation may well be justified in this case.

Because there is such a strong relationship between the proportion of dry grids and livestock densities, it is possible that the importance of the other independent parameters is overridden. If the index of water availability is excluded from the analyses then, indeed, additional parameters are identified as significant predictors of animal numbers. On an annual basis, for both cattle and TLU, four variables are extracted - %grass, %cultivation, annual rainfall, and total tsetse densities, of which the first three are postive, and the last, negative. The total percentage variaion explained by these parameters is 90-91%. In both, % grass cover is the primary predictor ($p < 0.01$), followed by % cultivation, rainfall and tsetse density for cattle, and rainfall, % cultivation and tsetse density for total TLU.

Season by season, the primary predictors for cattle and TLU, excluding dry season dry grids, are cultivation then rainfall in the dry season, and rainfall then vegetation density in the wet season. In neither, was % grass cover identified by the stepwise regressions. This demonstrates the variable nature of the dependence of livestock on grass disccussed in the preceding sections.

The densities of pastoralists' sheep and goats (excluding those owned by arable farmers) are best predicted on an annual basis, by rainfall then the proportion of dry grids in the dry season ($r = 0.84$, $p<0.01$). This suggests that most such small ruminants are to be found in the well watered parts of the regions with comparatively low rainfall. If the seasons are considered separately, then the only significant predictor extracted by stepwise regression is vegetation density in the wet season, with which they are negatively correlated.

Pastoralist habitation density is exclusively related to percentage grass cover, in both seasons, but more strongly so in the dry. This indicates that the relationship with water availability, described in section 3.5.2.3.4 above, is due to autocorrelation between water availability and grass cover, and emphasizes the suggestion that pastoralists' habitation is more closely linked to prime grazing than are the livestock they own.

The ratios between human and livestock populations in relation to environmental factors can also be examined using stepwise regression. The number of Tropical Livestock Units per pastoralist dwelling is related to none of the measures avialable during the wet season, but during the dry season, is primarily (and positively) linked to percentage grass cover. High annual rainfall and widespread surface water also contribute significantly to the dry season regression. Thus, more livestock are associated with each pastoralist structure in those localities which have the most grass, and are the best watered.

In contrast, the number of cattle per pastoralist habitation in both wet and dry seasons is related primarily to the overall levels of cultivation, most significantly so in the dry season. This is almost certainly explained by the fact that a substantial number of cultivators also own cattle, so that in relation to the number of livestock, the number of pure pastoralists falls in cropped areas. However, other factors are shown to be significant by the analyses, notably reduced tsetse index in the wet season and high annual rainfall for the dry season.

Finally, the proportion of total Tropical Livestock Units that are made up of cattle is negatively associated with the proportion of dry grids during the dry season, but only significantly so in the dry season itself ($p < 0.01$). This confirms that cattle increasingly become the predominant livestock in terms of biomass as the land becomes less arid.

In conclusion, these multivariate analyses show convincingly that water availabilty, is the primary predictor of livetsok densities, and many of the other parameters associated with the animals. Cultivation and vegetation in their various forms act, in the main, only as modifiying influences.

3.6 SUMMARY OF THE MAJOR FINDINGS PRESENTED IN SECTION THREE

The low level aerial surveys carried out in West Africa by ILCA and RIM between 1979 and 1985 have a number of important features in common, which make the combined dataset unique. A standard methodology of Systematic Recconaissance Flights (SRF) has been used throughout. A total of more than a quarter of a million square kilometers have been surveyed, covering selected regions of each of the four major Ecological Zones, in both wet and dry seasons, at sampling intensities of between 5 - 20%. Essentially similar information concerning livestock numbers, human habitation, cultivation levls and various environmental parameters has been collected throughout a wide range of disparate sites. Although some information has been recorded on a site specific basis it has nevertheless been possible to group the parameters in such a way to make general comparison valid. Further, because of the sytematic and unstratified sampling strategy employed, it is still possible to add new information to the existing dataset, so that yet more trends, stratified populations and predictors can be identified.

Following the development of new techniques in statistical analysis, which give greater precision (see: section 2 and Marriot and Wint, 1985), relatively small differences in the aerial survey estimates of cattle densities have now been shown to be significant, particularly where the sites concerned are large. Though not yet specifically tested, it is very likely this is equally valid for measures of other parameters recorded. Thus, the figures presented can be considered to be stastically reliable both for the purposes of comparison and future monitoring.

The present report has deliberately adopted a 'broad brush' approach. A number of important findings have emerged, some of which confirm and quantify long held hypotheses, and others which strongly suggest that current concepts are in need of substantial revision. The major findings are summarised below:

3.6.1 Zonal Stocking Levels.

Large scale trends in livestock density - 5.4, 16.1, 12.9 and 26.4 TLU per square kilometer for the Arid, Semi-Arid, Sub-Humid and Highland Zones respectively - conform, broadly speaking, to established concepts. Camels are effectively limited to the Arid Zone, where pastoralists' sheep and goats also constitute a relatively high proportion of the total livestock biomass. However, in terms of stocking rates, the Semi-Arid and Sub-Humid Zones are shown to be more similar than has been previously thought - both support similar densitiies in typical rangeland, and both contain very atypical seasonal refuges (the Inland Delta in Mali, and the Jos and Mambilla plateaux in Nigeria) which sustain very much higher livestock populations, from which the cattle are moved as the conditions ameliorate.

3.6.2 National Livestock Population Estimates.

Depending on area, the present results suggest that there are between 1.5 and 4 times as many cattle in Mali and Niger than hitherto accepted. These may reflect the wider geographical coverage of aerial surveys which include very remote areas, not amenable to ground census. If anything, aerial survey is likely to undercount livestock populations (particularly of small ruminants), so actual densites may be even higher. In Nigeria, the aerial survey estimate of the National cattle herd is similar to previosly published figures, but only if the heavily stocked Highlands are ignored. However, instead of the Semi-Arid Zone supporting substantially greater cattle numbers than the Sub-humid Zone, as was previously thought to be the case, the cattle population appeared to be much more equitably divided between the two.

3.6.3 Limited Growth Potential.

Given the relatively high livestock densities, the fact that much of the land is unavailable as pasture, and the constraints on maximum sustainable stocking rate imposed by periodic environmental fluctuations, the potential for any increase livestock densities in the Arid and Semi-Arid Zones is debatable. At the most a 50% rise might be envisaged. In the Sub-Humid Zone, an expansion of between 50-100% appears to be feasible. The Highlands are already substantially overstocked.

3.6.4 Zonal Trends of Environmental Parameters.

The proportion of land under cultivation was lowest in the Arid Zone with an average of some 3%: highest cultivation levels were found in the Semi-Arid Zone where 21% of the land was cultivated; Sub-Humid Zone levels were intermediate at 9%. Vegetation density and water availability tended to decrease from north to south. No clear trends were discernable for grass cover.

3.6.5 Zonal Trends in Human Habitation.

Not surprisingly the density of arable farmer habitation showed a similar pattern to cultivation, being lowest (>0.3 per square kilometer) in the Arid Zone, higher (19 per square kilometer) in the Semi-Arid Zone, and intermediate (12 per square kilometer) in the Sub-Humid Zone. Highest levels (23 per square kilometer) were found in the Mambilla Highlands which supports a substantial agropastoral community. The density of pastoralist habitation had a much more limited range, from a low of 0.4 per square kilometer in the Arid Zone to a high of 1.7 per square kilometer, with Semi-Arid and Sub Humid Zone levels being intermediate.

3.6.6 Arable:Pastoral Ratios.

Most of the measures taken show that the relative importance of the livestock sector decreases southwards; the ratio of arable to pastoral dwelling density rises; and the number of cattle per arable habitation drops. However, the number of cattle per cultivated hectare is surprisingly consistent in all three major Zones, excluding the Highlands, which suggests that in terms of land area used, the relative importance of the pastoral and arable farming sectors if fairly constant.

3.6.7 Seasonal Changes in Distribution and Density.

The distribution maps produced for each site often show that livestock are not where they were initially assumed to be. Similarly, recorded seasonal changes in density are frequently less than previously assumed.

3.6.8 Environmental Correlates of Livestock Distribution.

A particularly important finding of the aerial surveys is that similar variables act as predictors of cattle livestock distribution throughout ILCA's sphere of activity in West Africa. These parameters include water availability, annual rainfall, %grass cover, % cultivation, and in the southern two Zones, vegetation density. The fact that these variable act as highly significant predictors, in spite of the wide geographical and environmental variability of the sites, serves to emphasize their general validity.

3.6.9 Indicators of Potential Maximum Stocking Levels.

All these relationships predict very similar livestock densities at optimal environmental conditions. This suggests that, in all three Zones, in the absence of environmental constraints, and without additional external input, the natural maximum stocking levels are some some 60-64 cattle or 44-48 TLU per square kilometer in the wet season, but somewhat lower, at approximately 38-49 cattle or 28-36 TLU per square kilometer, in the dry season.

3.6.10 The Importance of Dry Season Water.

In a multivariate analysis of all parameters considered the availability of water during the dry season was found to be of overriding importance, which predicts both dry and wet season cattle densities to a very high level. This relationship, however, cannot necessarily be assumed to be directly causal. Rather, water availability may reflect pasture quality and duration, as well as the presence of drinking water, and so be linked indirectly to cattle densities. The remaining parameters - cultivation and its associated markets, grass cover, and vegetation density - act only to modify the influence of the primary predictor.

4. SELECTED APPLICATIONS OF AERIAL SURVEY DATA.

This section is incomplete, but has been included, in outline, within the working draft to provide some subjects for discussion. The Figures and Tables have been extracted directly from their parent reports, as possible examples only, and so the numbering is inconsistent with the rest of the manuscript, as well as within this section itself.

4.1 EXTRAPOLATIONS OF HUMAN POPULATION LEVELS.

The extrapolation of human population levels from estimates of habitation numbers is, at first sight, dependent on a detailed knowledge of the number of occupants per hut for each habitation category recorded. Such information is available for only a few of the aerial survey sites, and so few estimates of this type have been made. A striking example of the potential value of such data can be seen from the surveys of the Niger Range and Livestock project zone, where the pastoral population of the area was assumed to be some 50,000 before the survey, and was revised upwards by a factor of four, to some 200,000 after it. See Table 4.1.2 from Pastoral Development in Central Niger (Swift ed., 1984)

Evidence presented in RIM (???) does, however, suggest that counts of habitation numbers alone may provide reasonably accurate estimates of human population numbers, which would be of considerable value in those countries where official census figures are long out of date. Using the data from a photographic survey of Bauchi State, Nigeria, it was shown that the number of arable farmer habitations as estimated from the air, and the number of farming families estimated from village listing procedures on the ground, was closely correlated ($r = 0.93$). Should this relationship be found to hold true in other areas, then both family size and hut occupancy levels could be used to convert habitation counts to actual population levels. It must be emphasised, at this point, that such population estimates would refer to the rural population only, and would not include the urban people, as counting habitation numbers in large towns is particularly difficult unless a complete photographic coverage is assured.

4.2 CULTIVATION AND HUMAN HABITATION

Low level photographic survey of Bauchi State, Nigeria - 66,000 sq km
See: Figure 1 for sample vertical colour photograph and sampling points
See: cultivation distribution Map 1 of RIM's report.
Overall and regional estimates of cultivated land
Assessment of State crop production and food balance
Overall and regional estimates of human habitation
Allocation of project resources
Optimal siting of Farm Service Centres and fertilizer stores
Priority areas for feeder road construction
Framework for monitoring and evaluation

4.3 CROP IDENTIFICATION AND CROPPING PATTERNS

4.3 1 Crop Identification.

In the majority of the livestock surveys conducted by the Aerial Survey Unit. little attempt was made to systematically record the species of crops being cultivated. and only broad scale observations were made to assist the interpretation of livestock distributions. Only in the Mali Delta. where both rice and cereals are grown. but in effectively mutually exclusive areas. was crop type differentiated. Here. rice was largely limited to the Inundated Plans. and cereals to the areas outside them

An experimental survey was. however. undertaken by RIM. in cooperation with the Agricultural Planning. Monitoring and Evaluation Project Unit of Nigeria. in which cropping levels. crop types and stand densities were assessed using both wide angle and telephoto photography. The area covered - the Azare Region of northern Bauchi State - comprised 4.250 square kilometers of comparatively intensively cropped land. and was flown towards the end of the cropping season. For location see cultivation map of Bacuhi State and for example of simultaneous wide angle and telephoto photography see colour photographs in Figures 2 and 3.

The results obtained were compared to information collected on the ground. and the accuracy of the techniques thus evaluated. To quote from the conclusions of RIM (???) "The aerial estimate of the area of the four principal crops was within 4% of the ground based survey estimate. The discrepancies noted between aerial and ground data were considered to be mainly due to poor timing of the flights....which should have been timed to coincide with the maturity or harvest of early millet."

This suggests that the experiment was a definite success. given the comparative costs of an aerial survey and a large scale ground investigation. and that the approach used is one that ILCA would do well to adopt in view of the oft-quoted links between cultivation to livestock production. Thus. though livestock counts were not made for this area which can be directly compared to the figures from the other surveys. the data collected are briefly discussed so as to illustrate this potential application of low level aerial survey techniques.

Almost 40% of the total land area was found to be under cultivation. with a further 15% being identified as recent fallow. Millet was the predominant crop grown. occupying some 70% of the cultivated land area. either as the sole crop. or mixed with other species. Sorghum was seen on 47% of the cultivated land. and a further 17% consisted of undifferentiated cereal species. The two other major crop species - cowpea and groundnut - were recorded over 32% and 8% of the cropped ground area respectively.

About a quarter of the millet was sole cropped. the remainder being in two or three crop mixtures. Sorghum was grown predominantly with one or two other crops. and both cowpea and groundnuts were almost exclusively mixed with other species. The most frequent crop mixtures or enterprises were sole millet. sole sorghum. sorghum and millet. and millet with cowpea. which together accounted for 54% of the land area under cultivation. or some 20% of the total land area.

Particular concentration areas were not apparent for any crop type or enterprise. partly as the distributions of all the crops and crop mixtures overlapped to a very considerable degree. and were essentially fairly evenly dispersed throughout the survey site.

4.3.2 Stand Density.

Stand densities of all the major crops and crop mixtures were made where photographic clarity was sufficient, and then compared with counts made on the ground. The phtographic counts, particularly of millet were reasonably close to the ground truth figures, except those for ground nuts for which the air derived figure was approximately twice that of the ground counts. If the ground counts can be taken to be truly representative of the areas covered by air, then the aerial counts must be assumed to be only sufficiently accurate to provide approximate estimtes of stand densities. It seems likely however that much of the discrepancy between the two counts can be accounted for by the fact that the ground truth sites were relatively small, and easily accessible, whilst the aerial counts were often remote. Thus the two counts may not have been made from statistically equivalent populations.

4.4 SITING OF LIVESTOCK DEVELOPMENT FOCI

Estimation of livestock population and human habitation levels within defined ranges of selected centres in order to identify development focii where intervention options will be in reach of maximum catchment populations. See Map 11 of wet season cattle distribution and Table 18 from RIM's study of Southern Gongala State.

4.5 IDENTIFICATION OF LAND SUITABLE FOR LIVESTOCK

Amalgamation of environmental parameters (eg presence of tsetse, water availability, topography, dense vegetation cover, terrain) to produce composite maps of land suitablity to highlight regions of high and low potential for expansion and development. See Map 10 from RIM's study of Southern Gongala State.

4.6 ASSESSMENT OF KEY MACRO ECONOMIC INFORMATION.

Combination of aerial livestock population estimates and marketing information collected on the ground to derive overall macro-economic indicators. See Table 19 from RIM's study of Southern Gongala State.

4.7 SATELLITE - AIR - GROUND LINKAGE

4.3.1 Aerial Survey's Contribution to a Drought Early Warning System.

4.3.2 Validation of Vegetation and Land Use Interpretation.

4.3.3 Assessing Populations using both Air and Ground Data.

Goats
Muturu
Pigs
House types

4.3.4 Forestry: Estimating Wood Volumes and Fuel Wood Availability.

4.8 SITING AND EVALUATION OF DEVELOPMENT INTERVENTIONS

4.8.1 Siting Development Options.

4.8.2 Evaluating Grazing Reserves

4.9 RECORDING PARAMETERS OF SPECIFIC INTEREST TO A SITE.

4.9.1 Erosion and Burning.

Two parameters relevant to rangeland condition have recorded with some regularity - gully and sheet erosion as being indicative of overgrazing: and the degree of burning which may stimulate grass growth in the short term. Burning was evaluated as a percentage of land effected, while erosion was assessed on a ranked scale from 1 to 5.

In RIM's study of Southern Gongola State sheet erosion was seen fairly regularly along migration routes and, in the drier regions, near surface water sources. It was, however, only outstandingly severe on the high grasslands of the Mambila Plateau, were substantial sections of grazing appeared to be more or less unusable, even in the wet season. Gully erosion was also freqently observed, often in association with sheet erosion, and mostly on the edges of elevated land which supported relatively high levels of cultivation. Again, it was only in the Mambila Plateau, that the levels of gullying could be described as severe.

Burning was both ubiquitous and generally affected a large fraction of the land surveyed in most areas, though it was only evident in the dry seasons - rarely had less than 50% of the land surface been burned at some time during the year, except in the Mali Delta where the 'zone brulee' was restricted to the floodplains.

Table 4.1.2 Estimated project zone pastoral and agropastoral population

	Total number of dwellings[1]			Estimated total population[2]			
	May 1981	October 1981	September 1982	May 1981	October 1981	September 1982	Mean[1]
1. Twareg							
- mat tents	10,215 (17)	5,681 (20)	6,550 (19)	51,075	28,405	32,750	37,410 (26)
- leather tents	12,031 (18)	10,144 (18)	7,201 (24)	60,155	50,720	36,005	48,960 (20)[3]
- sedentary	12,950 (29)	13,977 (38)	19,001 (31)	64,750	69,885	95,005	76,547 (17)
2. WoDaaBe/FulBe	5,709 (21)	6,244 (20)	6,954 (25)	34,254	37,464	41,724	37,814 (8)
3. Arabs	-	879 (74)	-	-	4,395	-	4,395
Total	40,905	36,925	39,706	210,234	190,869	205,484	202,196 (4)

Source: Project air survey (Milligan 1982 a, b, c)

Notes:

1. Coefficient of variation in brackets
2. For assumptions used to calculate number of inhabitants/dwelliing see text.
3. Mean is too high due to inclusion of Arabs in this category in May and September surveys. See text for discussion.

Map 1 Distribution of Cultivation in Bauchi State

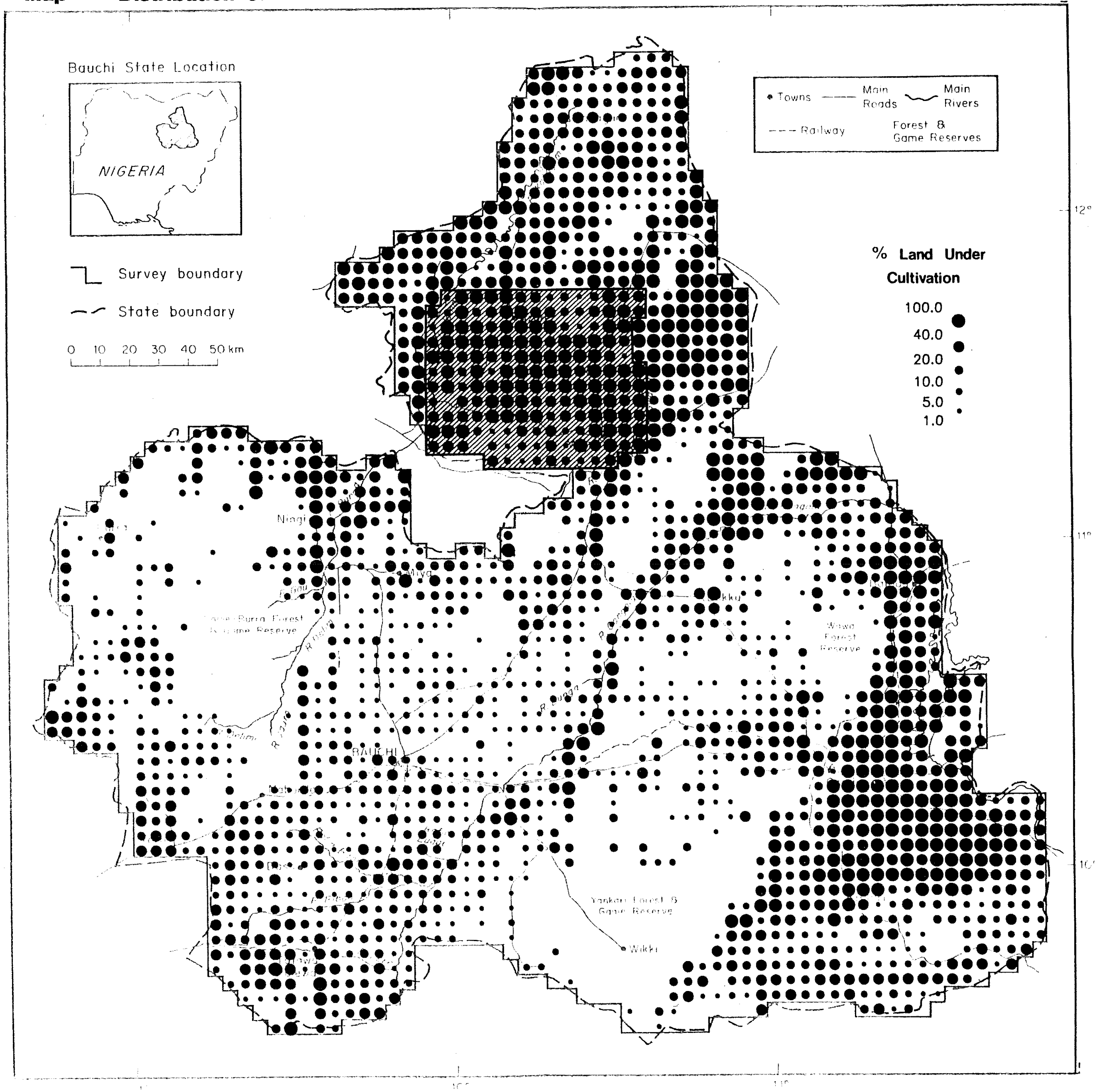
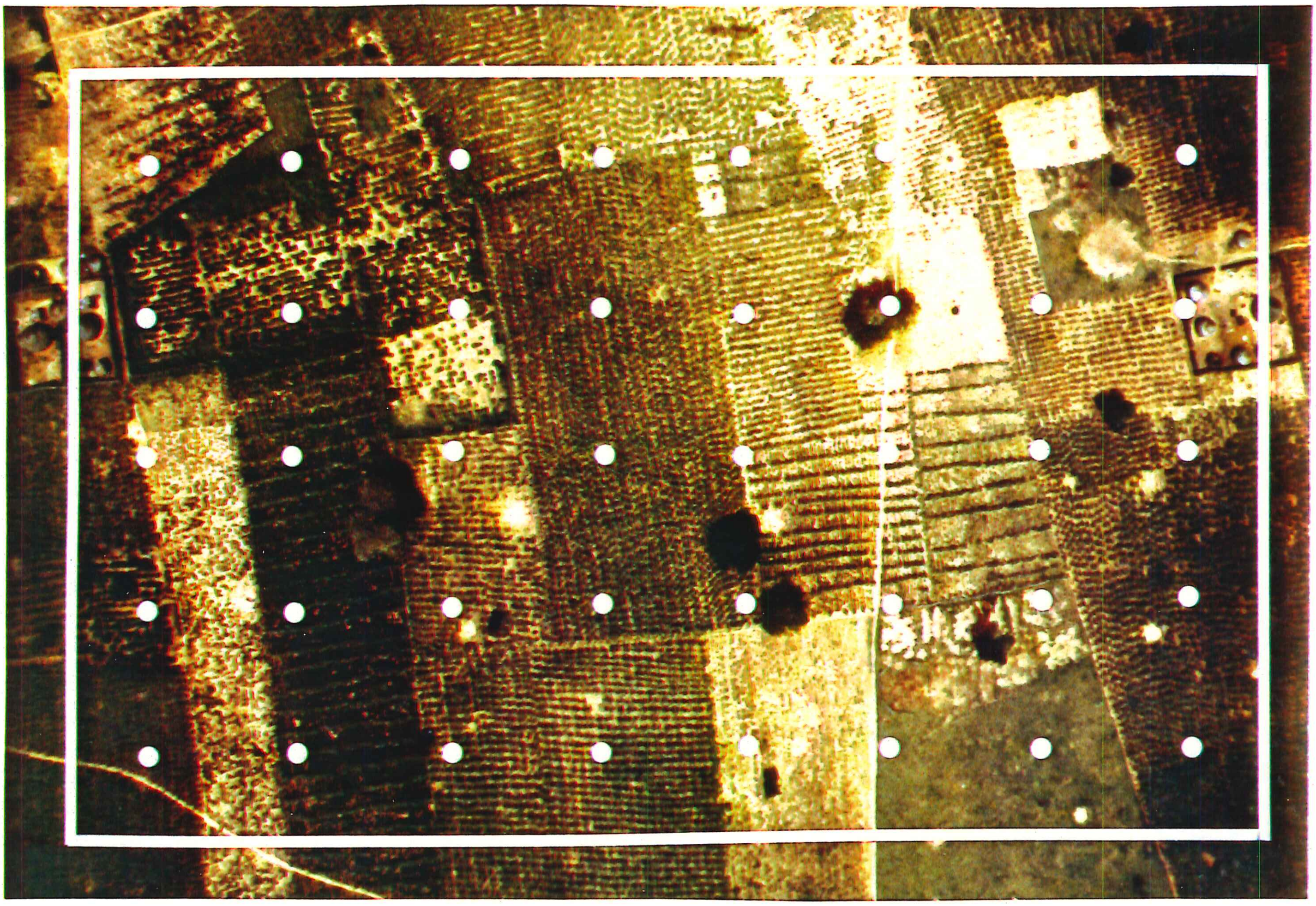
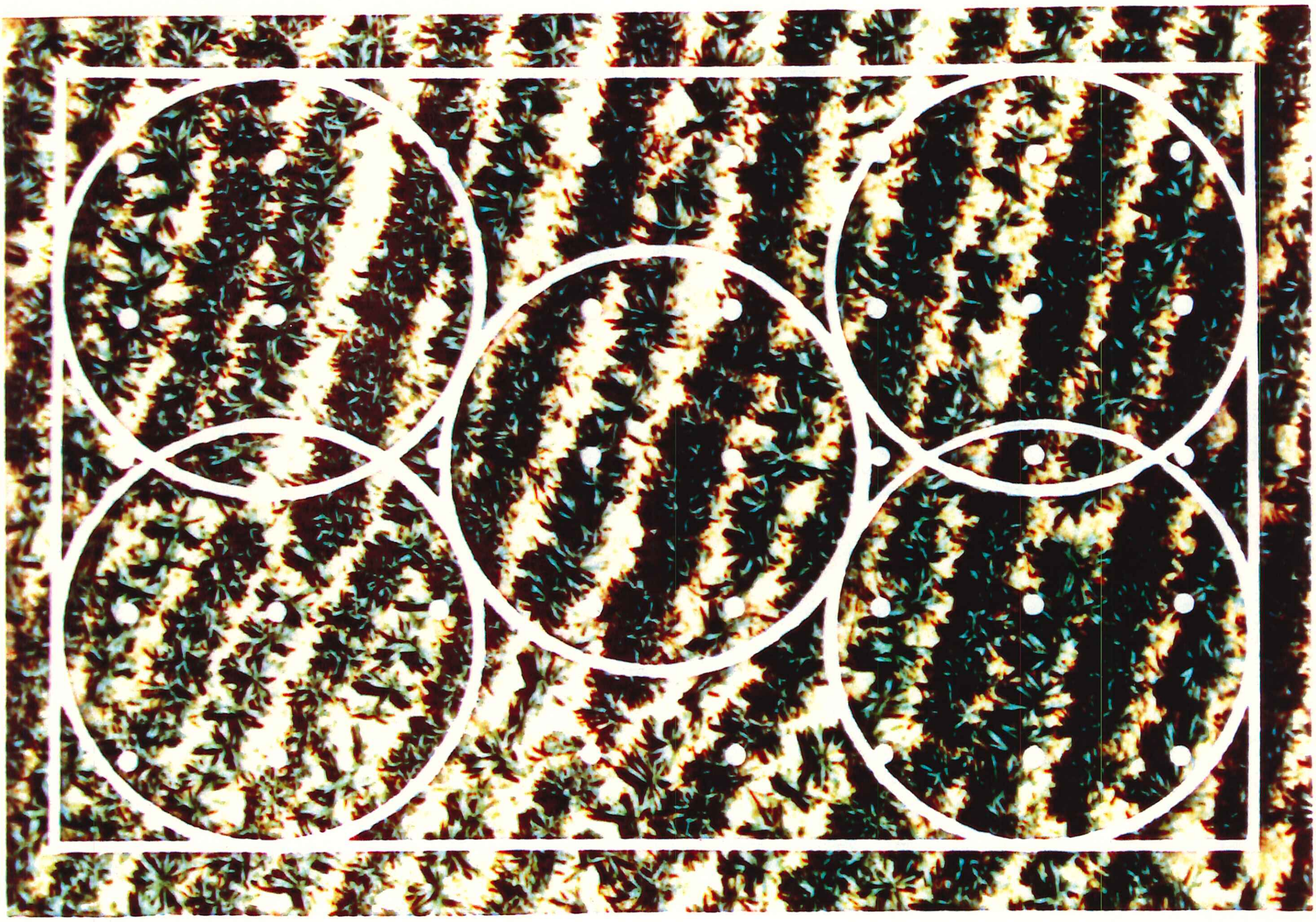


FIGURE 1: REPRESENTATION OF PROJECTED WIDE ANGLE IMAGE AND SAMPLING SYSTEM.



8 x 5 array of white dots indicate 40 sampling points for land use assessment. White rectangle shows the sampling frame within which buildings were counted.

FIGURE 2: REPRESENTATION OF PROJECTED TELEPHOTO IMAGE AND SAMPLING SYSTEM.



The white rectangle represents the sampling frame within which the number of crop enterprises was counted; the 8 x 5 array of white dots indicate the 40 sampling points for assessing the relative size of each enterprise; and the five circles demarcate alternative areas for counting crop stands.

FIGURE 3: WIDE ANGLE AND TELEPHOTO PAIR - MATURE MILLET AND SORGHUM MIXTURE.