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PROSPECTS FOR THE DEVELOPMENT OF CATTLE PRODUCTION ON MIXED FARMS IN THE PASTORAL ZONE OF NIGER: A SUMMARY

by

Edward D. Eddy, III

CENTER FOR RESEARCH ON ECONOMIC DEVELOPMENT
The University of Michigan
Ann Arbor, Michigan 48109

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ABSTRACT

The paper is based on the results of a survey conducted by the author in 1976/77 among forty-five households in the Azawak region of Niger. The sample covered three populations: Haussa farmers and traders, Tuareg traders and wage laborers, and semi-nomadic Tuareg. Focusing on the latter group, a linear programming model of grain and livestock production is formulated. The analysis suggests that with the constraints imposed by consumption requirements and labor availability, semi-nomadic Tuareg are currently producing at optimal or near-optimal levels, as determined by value-maximizing behavior. Sensitivity analyses indicate that marginal changes in technologies and prices will have only a minor impact on the desirability of cattle production and are unlikely to reduce the area planted to grain. Structural reforms in grain markets and property law are required to induce a shift into cattle production by any of the populations covered by the survey.

SOMMAIRE

Ce rapport est fondé sur les résultats d'une étude dirigée par l'auteur en 1976/77 couvrant quarante-cinq familles dans la région Azawak du Niger. Trois populations distinctes ont été comprises dans l'échantillon: des paysans et commerçants Haussa, des commerçants et travailleurs ruraux salariés Touareg, et des Touareg semi-nomades. Ce dernier groupe a fait l'objet d'un modèle à programmation linéaire portant sur la production céréalière et animale.

On déduit des résultats de cette analyse qu'étant données les contraintes imposées par les besoins d'autoconsommation et la disponibilité de main d'oeuvre, les Touareg semi-nomades opèrent actuellement à des niveaux optima ou quasi-optima de production, jugés sur la base d'une fonction économique visant à maximiser la valeur du produit. Les analyses de sensibilité du modèle indiquent que des changements marginaux sur la technologie et les prix n'auront qu'un impact trés réduit sur la profitabilité de la production de bétail, et qu'ils n'entraineront vraisemblablement pas une diminution de la superficie consacrée à la culture céréalière. On n'observera donc un mouvement en faveur de la production de gros bétail parmi les populations étudiées qu'à la suite de réformes structurelles des marchés céréaliers et de la propriété foncière.

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Research Objectives

This paper draws on the results of a survey conducted by the author in and around a small market town on the southern edge of the Sahara Desert in western Niger. The survey ran from June 1976 to June 1977 and involved intensive interviewing among forty-five Haussa and Tuareg mixed farm households.[1]

From a national viewpoint, the area covered by the survey appears to be better adapted to livestock production than the production of grain. In particular, extensive grain cultivation in such an arid area can eliminate the permanent vegetative cover. This expedites the process of desertification.

For these and other reasons to be explained below, many development planners believe that residents of the pastoral zone, which would include the survey area and similar areas, should be forced or encouraged to specialize in cattle production. Nonetheless, grain production persists along the southern edge of the pastoral zone, and the cattle herds of mixed farmers are quite small. It appears that most residents of the southern pastoral zone prefer to combine millet and sorghum crops with goat production rather than cattle.

To investigate some of the factors behind the current production patterns, a linear programming model of a representative Tuareg mixed farming system is developed. The model is then applied to simulate the effects of three major policy options intended to promote the expansion of livestock production at the expense of grain crops. The policy options in question are: 1) grants of cattle to mixed farmers (herd reconstitution programs); 2) decreases in the price of grain, with the nominal value of livestock output remaining constant; and 3) technological innovations which would increase milk yields. The results of the analysis

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[1] In this context, "mixed farm" refers to producers of both grain and livestock.

suggest that, given 1976 prices and the set of assumptions underlying the model, none of the above interventions are likely to induce even the best endowed Tuareg mixed farms to abandon grain production and devote all available resources to the production of cattle.

This implies that development planners must reconsider strategies currently proposed for the pastoral zone. As an alternative to such strategies, several policy recommendations are put forward. Such schemes might relieve the major labor constraints restricting crop and livestock production, as well as provide a means of protecting the southern pastoral zone from further desertification.

The first section of the paper introduces the reader to the environment within which the research was conducted and to which the results of the analysis might be applied. It is followed by a brief description of the methodology employed for the survey and the ensuing analysis. The third section describes and compares the three production systems covered by the survey (Bush Tuareg, Village Tuareg, and Haussa). The use of inputs (labor, land, and livestock) and the magnitude and patterns of disposal of agricultural output are discussed in this section. The fourth section contains a description of the average seasonal labor requirements of Bush Tuareg agricultural enterprises, broken down by the major activities associated with each enterprise. The fifth section contains the analysis of Bush Tuareg agricultural production, this system having been chosen as the most representative of the majority of residents of the southern pastoral zone. The final sections of the paper present the conclusions which may be drawn from the analysis and a discussion of the policy recommendations mentioned above. For a more exhaustive treatment of the topic, the reader is referred to the research monograph on which this paper is based.[1]

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[1]Eddy, Edward D., Labor and Land Use on Mixed Farms in the Pastoral Zone of Niger, Center for Research on Economic Development, University of Michigan, and USAID, 1979.

Introduction to the Research Site

Location of the Research Site: The Pastoral Zone and The Azawak Region.-- The location of the pastoral zone in Niger is indicated by the dotted area in Figure 1. The pastoral zone is defined as the area where cattle production is possible in all seasons of the year (SEDES, 1973). This corresponds to the area proposed for the specialized livestock production zone, as described above. It also roughly corresponds to an eco-climatic zone variously defined as the northern Sahel or sub-desert. Average annual rainfall within this zone varies from 150 mm in the north to 350 mm in the south.

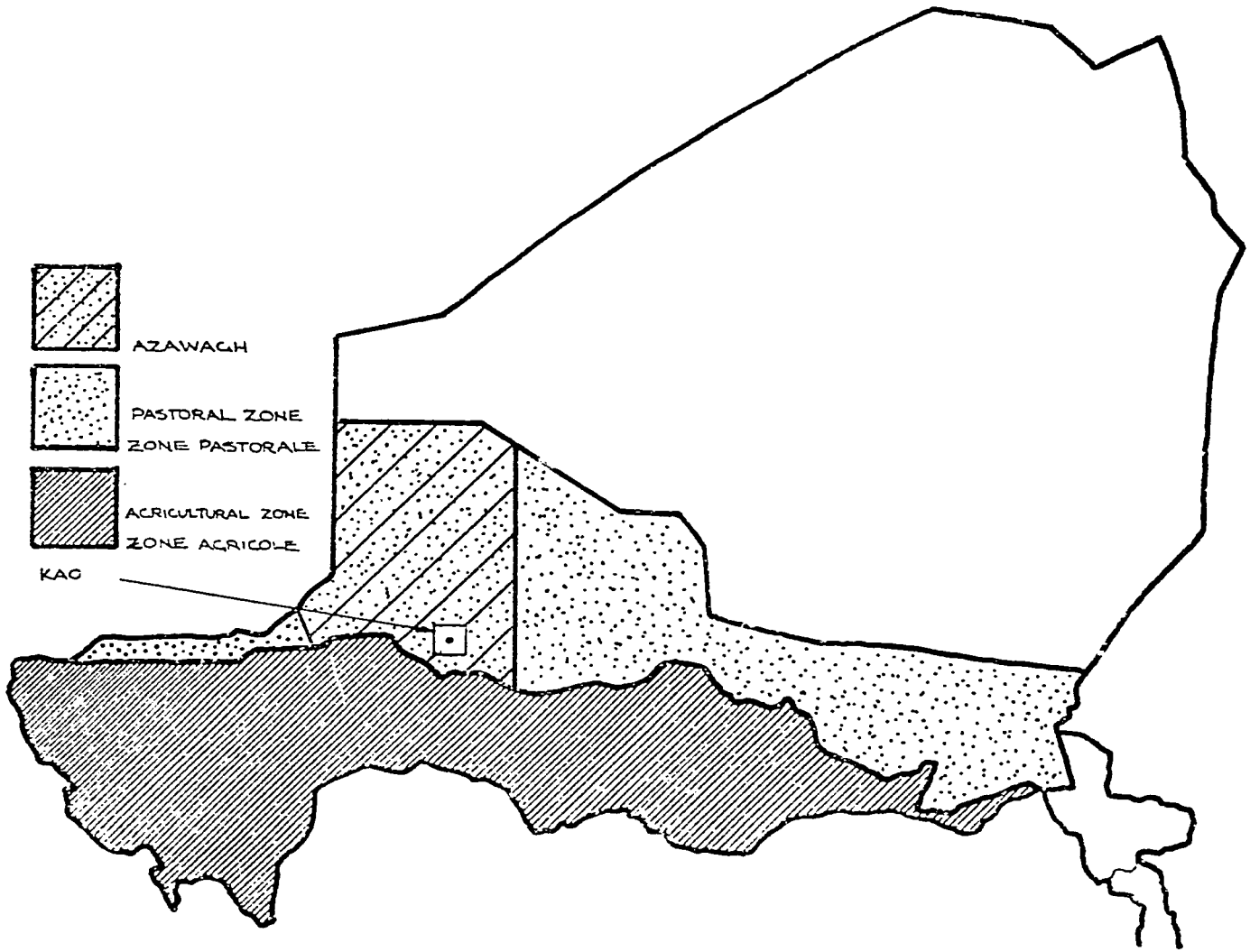
The pastoral zone forms a fragile buffer between the more densely populated grain-producing areas to the south and the practically uninhabited desert to the north. There is enough rain in the area to support grasses, but rarely enough, even on the southern fringe, to support rainfed agriculture. With little interference from grain fields in most areas and adequate water supplies for livestock throughout the year, the open rangeland of the pastoral zone appears well suited for extensive livestock production.

Most of the western portion of the pastoral zone lies within a region known traditionally as the Azawak (see Figure 1). The research site is located in the southern portion of this region and along the southern edge of the pastoral zone. The populations covered by the survey inhabited a 900 square kilometer area, indicated in Figure 1, centered about the market town of Kao in the political subdivision known as the Tchin-Tabaraden Arrondissement (Tahoua Department).

Climate.-- Areas in the southern pastoral zone have one rainy season during the year, which usually runs from June to September. The rainy season is followed by a hot/wet season, which lasts until the dry winds blowing off the desert descend to the lower atmospheres in November. The desert winds mark the advent of the cold season, which lasts from November to March and is characterized by perpetual dust storms. As the area is desiccated by the desert winds, temperatures rise, reaching their annual maxima during the hot/dry season which lasts from March until the early rains in June.

FIGURE 1

AGRICULTURAL PRODUCTION ZONES IN NIGER



Average maximum and minimum temperatures during these seasons are indicated in Figure 2. The cold season at the beginning of the year is the time when the daily temperature differential is the greatest. During this season, air temperature may drop by as much as 17° C between late afternoon and nightfall.

The area along the southern edge of the pastoral zone, to which the results of the following analysis may be expected to apply, lies between the 300 and 350 mm isohyets of average annual rainfall, as indicated in Figure 3. As suggested above, the 350 mm isohyet roughly marks the southern boundary of the pastoral zone. Kao, the center of the survey area, received an average of 323 mm of rainfall annually during the period for which the isohyets in Figure 3 have been calculated.

However, average annual rainfall is an illusory statistic. The intertemporal and interspatial distribution of rainfall in such northern areas of West Africa is marked by extensive variability. Figure 4 indicates the extent of such variability over the seventeen-year period preceding the survey, during which annual rainfall at Kao ranged from 185 to 475 mm.

Figure 4 also suggests the importance of deviations from the mean level of precipitation. Mean annual rainfall for the first half of the period was well above the overall mean, whereas the mean for the second half was well below. The second half of the period was the time of the well-publicized Sahelian drought. Although the recent drought was not without precedent, it was unusual in that it was exacerbated by historical factors, to be described below.

Deviations from trend are as important for monthly or even daily variations in rainfall as for annual variations. The timing of the rains are as important as the amount, since the timing determines the composition of grasses on the range and may determine whether or not a crop yields anything at all. Heavy early rains, for instance, will favor rapidly maturing grasses, whereas deficit rainfall towards the end of the rainy season may eliminate some varieties from the range by preventing late-maturing grasses from bearing seed. The timing of the rains also influences labor patterns, as will be illustrated below.

FIGURE 2:

MEAN MONTHLY MINIMUM AND MAXIMUM TEMPERATURE:
TAHOUA, NIGER, 1960-1976

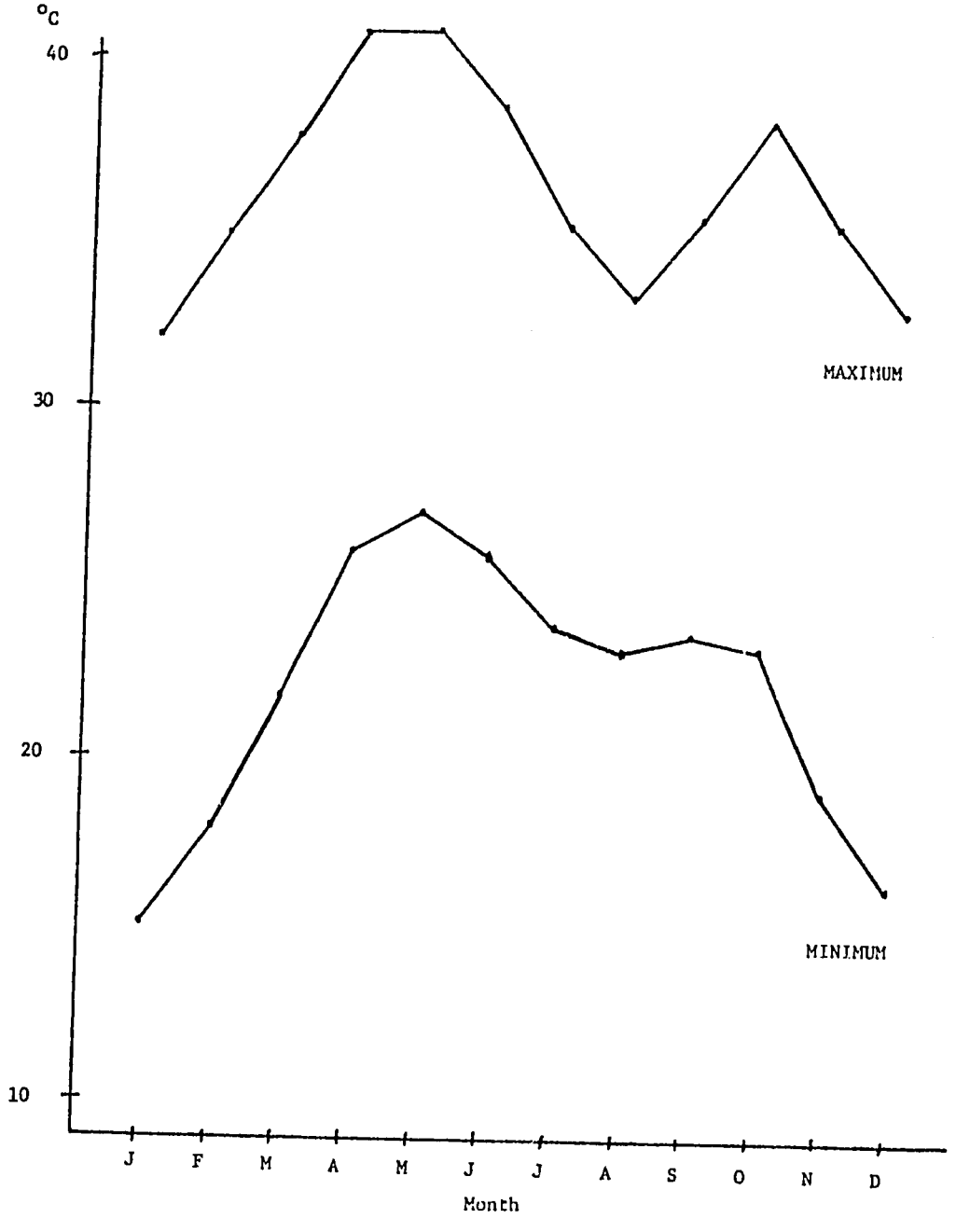


FIGURE 3: Isohyets of Average Annual Rainfall, NIGER, 1960-74 (mm.)

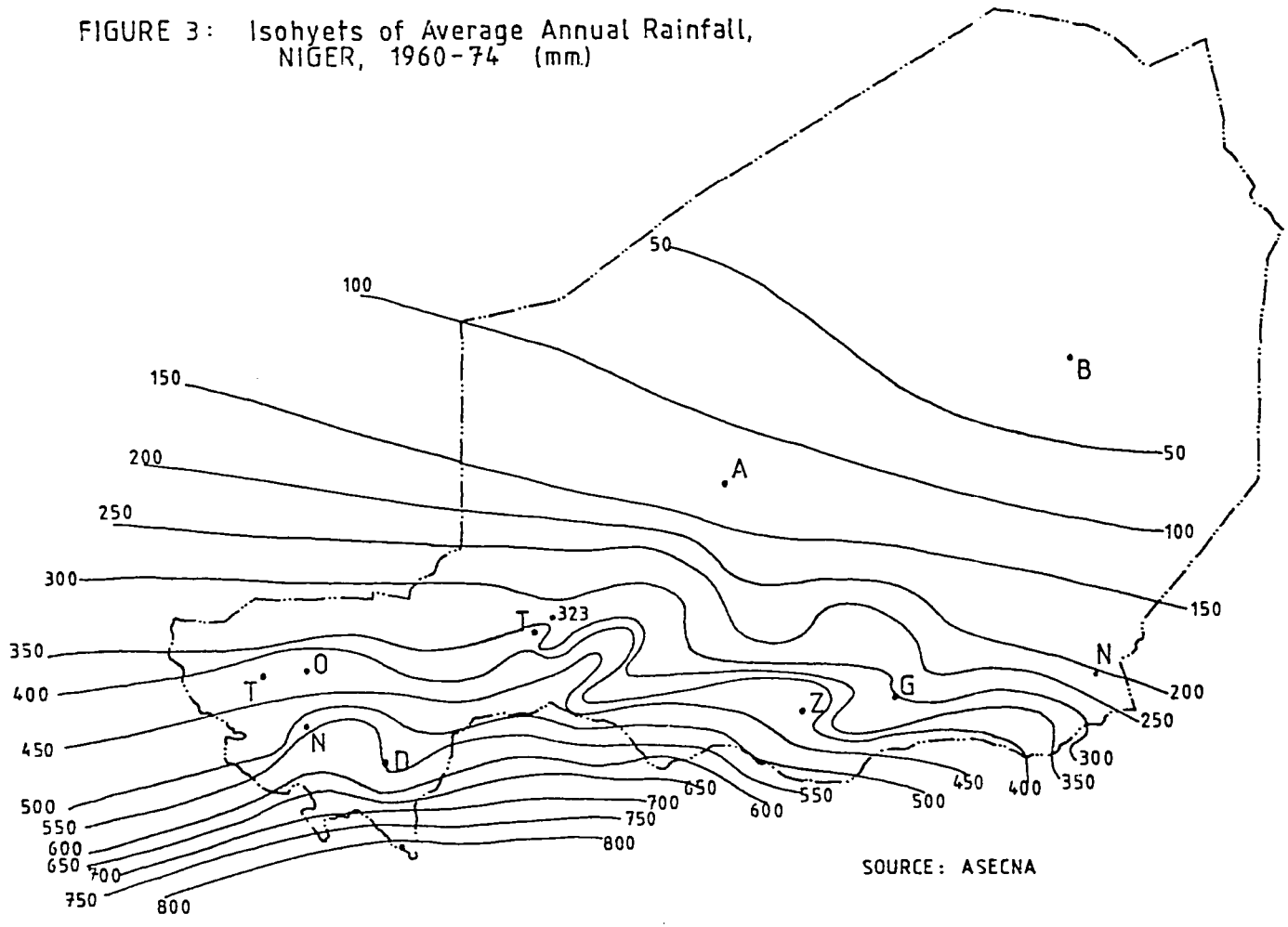
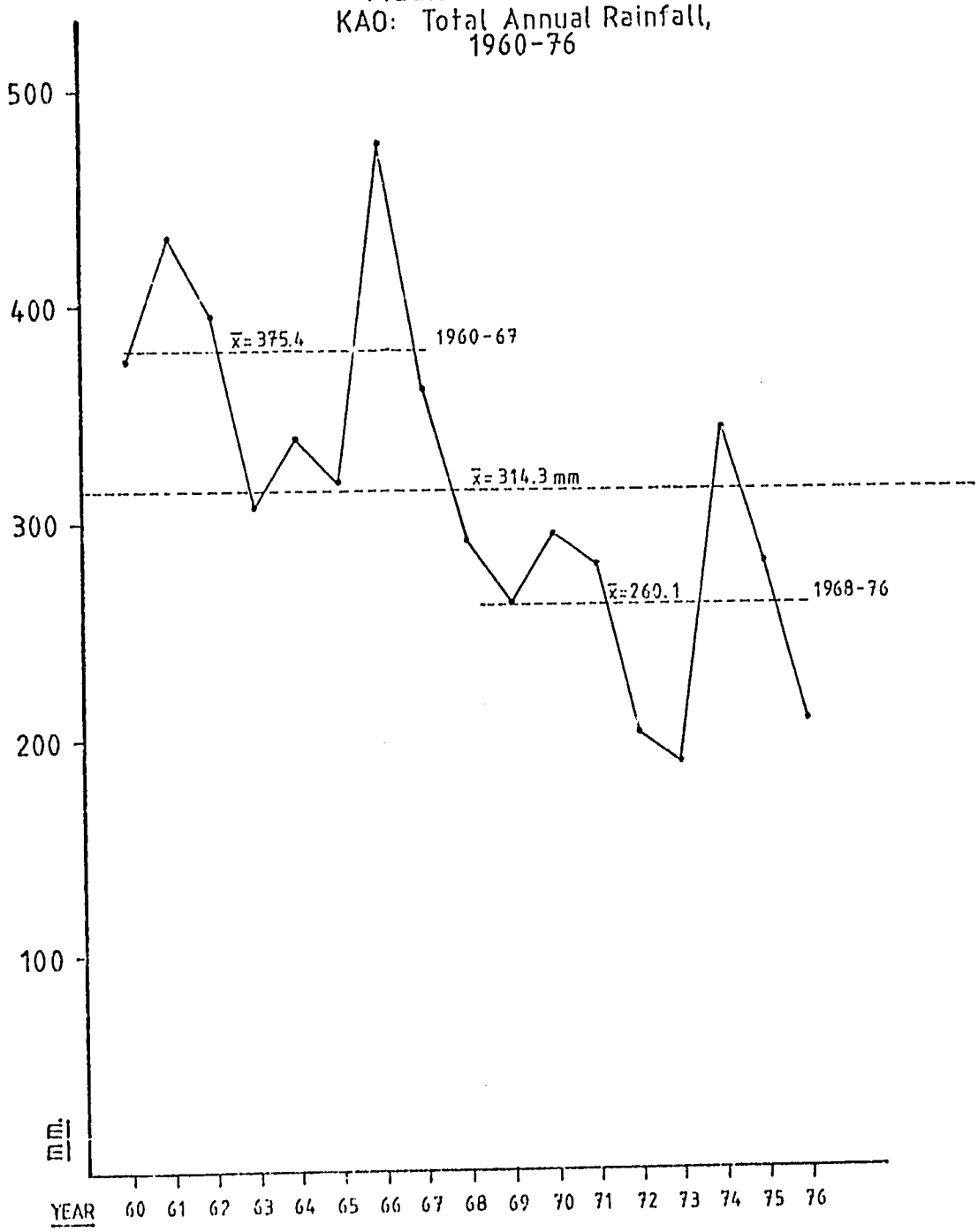


FIGURE 4:
KAO: Total Annual Rainfall, 1960-76



A comparison of the monthly distribution of rainfall at Kao since 1960 with that of the survey year suggests that the survey year may have been peculiar in two respects. First, heavy rains continued to fall later into the year than they had in the previous sixteen years, enabling some farmers to get a second sorghum harvest. Second, no useful rain fell during the last week of June and the first three weeks of July. This month-long drought occurred at the end of May and June plantings, and it devastated the millet crop. These peculiarities, combined with the unpredictability of precipitation in any year, make it difficult to extend the results of the production analysis described below to years other than the survey year.

People and Production Systems. -- Three major ethnic groups populate the Azawak: Tuareg, Haussa, and Fulani. In this context, ethnic affiliation is defined by the household's primary language, be that Haussa, Tamasheq, or Fulfulde. Unfortunately, it is impossible to say with any certainty in what proportion these ethnic groups are represented in the population of the Azawak. The purpose of the latest population census prior to the survey was to determine tax obligations, and therefore, the information collected is of dubious quality. Furthermore, inhabitants of the "nomad zone", which embraces the pastoral zone and the desert, are registered according to "nomad group" and "tribe" rather than place or region of residence. Thus, it is difficult to arrive at quantitative descriptions of the population, other than to say that the vast majority are Tuareg and that, in the southern portion of the region, Haussa households make up the next largest segment of the population.

The mixed farming systems covered by the author's survey could be divided into three groups: Haussa, Village Tuareg, and Bush Tuareg. The attributes of these three "production systems" are compared and contrasted in the third section of this paper. In addition to the mixed farming systems covered by the author's survey, the other major category of agricultural production systems in the pastoral zone could be characterized as nomadic pastoralism. The nomadic pastoralists do specialize in livestock production, relying on markets along the southern fringe of the pastoral zone for grain to supplement their diets. The pastoralists may not be present in areas such as the survey area throughout the year. During the

rainy season, they will move to the north to avoid conflicts with farmers over crop damages. During the dry season, they will move south to more permanent water sources and better dry season pastures. Generally, the pastoralists and their herds are in transit through the southern pastoral zone at the beginning of the rainy season and again during the hot wet season which follows the end of the rains.

The category of nomadic pastoralists can be further subdivided to distinguish Tuareg and Fulani livestock producers. The former raise primarily camels and small ruminants. They spend the greater part of the year in the northern pastoral zone. Traditionally, they are members of the more privileged classes of Tuareg society.

Fulani pastoralists produce cattle primarily, often in herds combined with sheep. Based on occasional interviews and time spent among Fulani households, the author determined that during the survey year, the typical household managed a herd of approximately fifty head of cattle. Usually this includes some animals which have been confided to the care of a member of the household, so that the number of animals managed does not always coincide with animal ownership by the household. Although this study does not deal directly with Tuareg or Fulani pastoralists, information concerning their production patterns is introduced where relevant to the analysis.

History. -- Prior to colonization, the Azawak was ruled by Tuareg warlords of the Iwllimeden Confederation, who apportioned the lands of the Azawak among themselves. Each warlord controlled the grazing and water rights in his allotted portion and further subdivided his fiefdom among the vassals and slaves subject to his rule. It was during this period that the ancestors of most of the Bush Tuareg households covered by the survey settled in the survey area to produce grain and pasture their herds. Although nominally they were members of the slave caste (iklan), they were a relatively independent group who owned and managed the productive resources from which they derived their livelihood, subject to the occasional payment of tribute to the aristocracy, a tribute which continues to be exacted to this day. In the pre-colonial era, these households planted

some grain by broadcasting seeds on the sides of the dunes, but devoted most of their efforts to livestock production. During the growing season, they would evacuate their animals to northern regions to participate in the salt cure and to allow pastures in the southern pastoral zone to grow out, a practice which has been abandoned in more recent years due to the influx of producers competing for the use of the range.

The Tuareg warlords were subdued by the French Army during the colonial struggle, and their system of land tenure was dissolved. Their subjugation cleared the way for a northward migration of Haussa grain producers into the pastoral zone during the period of abnormally high rainfall from 1948 to 1968. The village of Kao was settled during this period. The migrant Haussa grain producers introduced more intensive techniques involving the clearing of trees and grasses, and as the higher rainfall made grain production more profitable, the area planted to grain expanded rapidly.

During the same period, mechanized deep-bore water pumping stations were opened throughout the pastoral zone. The opening of the pumping stations, combined with the pacification of the Tuareg warlords, attracted a larger number of Fulani herds than the area had supported previously. These herds also grew more rapidly following the implementation of cattle vaccination programs.

Thus, prior to the 1968-1973 drought, the Azawak was subjected to an influx of Haussa grain producers and Fulani cattle herders, whose herds were growing at a greater rate due to the suppression of certain endemic diseases. These developments contributed to the devastating effects of the drought on the people, the animals, and the land resources of the pastoral zone. For example, many of the households designated as Village Tuareg had worked for members of the Tuareg aristocracy as herders prior to the drought. However, their patrons suffered substantial losses of animals during the drought, and these households were forced to move to villages such as Kao, which functioned as emergency food distribution centers. To support themselves, Village Tuareg households turned to commerce or work as laborers for Haussa households, who also had come to rely more heavily on trade as a source of income.

This tendency was furthered by the growth in the importance of Kao and similar villages in the southern pastoral zone as livestock markets. With the reduction in the supply of animals as a result of the drought, continued growth in demand for meat in coastal cities, and the commensurate rise in animal prices in the Sahel, livestock merchants moved to markets further north in the pastoral zone in an effort to obtain more advantageous prices. Thus, the chain of primary animal collection markets serving the pastoral zone has shifted north in recent years. This chain of events can be generalized as follows: (1) pacification of the pastoral zone by colonial forces; (2) the northward migration of grain producers into the pastoral zone during the two decades of abnormally high rainfall which preceded the recent drought; (3) greater growth in the cattle population due to the opening of mechanized water pumping stations and the elimination of endemic diseases; and (4) the emergence of market villages along the southern fringe of the pastoral zone. From this brief introduction to the environment within which the research was conducted, we move to a description of the survey methodology.

Research and Analytical Methodology

Sample Selection. -- The research team, including the author, lived at Kao throughout the course of the survey. The team consisted of three enumerators, a translator whose family lived with the author's family at the research site, two clerks, and several part-time assistants and consultants. The team arrived in Kao after completing the government clearance process in May 1976. At that time, a census of the village and surrounding Tuareg and Fulani encampments was conducted. The census was required to construct a proper sampling frame since, as mentioned above, reliable alternatives were available. To assist with the census and ensure the accuracy of the results, community leaders accompanied the research team.

For the purposes of the census and the survey, a "household" was defined as a group of people who eat out of the same pot. In the case of the populations covered by the survey, this definition delineated a management unit within which all members worked the same fields and tended the

same animals. Based on the results of the census, sixty-five such households were selected at random at a public drawing: forty-four from the village and twenty-one from a group of Tuareg encampments approximately five kilometers from the village. Of these sixty-five households, seventeen moved out of the survey area during the course of the survey and had to be dropped from the sample.

Survey Techniques.-- The basic work of the survey consisted of regular twice-weekly interviewing with each sample household. During these interviews, the enumerators collected information on the activities of each household member during the twelve daylight hours of each day, household cash flows during the relevant three or four-day period, exchanges in kind, production of agricultural commodities, and consumption of grain, meat, and milk. The enumerators then coded this information, using a coding system which was devised during the first month of the survey. Coding was verified weekly. The data then were punched directly from the questionnaires onto computer tape.

Each of the plots planted by sample households during the 1976 growing season was measured. The resulting angle/distance measurements were then spot-checked and coded by the author, so that the area of each plot could be calculated by computer. The results were returned to the author so that fields could be remeasured as necessary.

The measurement of agricultural output was based on local units of measure. For instance, since the grain harvest is stored on the head in bundles, the output from each field was marked down in bundles. Then, a representative sample of bundles of each type of grain was obtained from a number of households and the grain was removed from the head using the local processing methods. The bundle was weighed on a spring scale prior to processing, and the resulting quantity of grain was weighed on a balance scale.

Finally, market surveys were conducted to determine the prices at which to evaluate output. A sample of retail quantities of grain was purchased at each weekly market, then each purchase was weighed on a balance scale to determine the price per kilogram. Also, one or two enumerators remained in the livestock market throughout the day and, for as many

transactions as possible, recorded the purchase price, age, sex, breed, origin and destination of the animal, and occupations of the buyer and seller. These data were compiled and coded on market survey schedules, and, again, keypunching was done directly from these schedules.

Populations Covered by the Survey.-- As mentioned in the first section, the survey was restricted to mixed farm households. Some qualititative interviewing was conducted by the author at traditional gatherings of nomadic pastoralists in or around the survey area. However, such research was really tangential to the main survey.

The main survey covered the three types of mixed farm households discussed above: Haussa, Village Tuareg, and Bush Tuareg. In addition, the sample contained three Fulani households. However, since this subsample was too small and the households within it were not found to be representative of any major production system, these three households have been dropped from the subsequent analysis. The forty-five households remaining represented the three types of production systems in the following proportions: (1) Haussa: sixteen households: (2) Village Tuareg: seventeen households; and (3) Bush Tuareg: twelve households.

Analytical Methodology. -- The linear programming model presented in the sixth section of this paper applies directly to the production system represented by the twelve households in the Bush Tuareg subsample. From among the populations covered by the survey, the model was designed to represent the production system of Bush Tuareg households, for several reasons. First, Bush Tuareg households relied most heavily on household production as a source of food for subsistence needs. Second, from among the three subsamples, they derived the largest proportion of their cash income from agricultural enterprises, as opposed to commerce or wage labor, during the survey year. Third, Bush Tuareg households devoted the largest proportion of available labor resources to agricultural enterprises. Fourth, they relied least on hired labor to supplement household labor resources. These characteristics will be illustrated in the comparative analysis of the three production systems following this section. Finally, and most impor-

antly, based on the author's travels and life in the southern Azawak, on what little population data were available, and on secondary sources, the author concluded that the households in the Bush Tuareg subsample were the most representative of the largest segment of the population of mixed farmers in the southern Azawak. This segment could be characterized as semi-sedentary Tuareg subsistence crop and livestock producers, most of whom are of the iklan social class.

The model allows for selection among millet, sorghum, goat, and mixed goat and cattle enterprises, subject to labor, land, and subsistence constraints and certain other behavioral assumptions to be specified below. The model is then used to determine optimal enterprise combinations for both the average and large Bush Tuareg households. Separate solutions are obtained for the larger households, since only the larger households were engaged in cattle production during the survey year. In determining optimal enterprise combinations, the model is used to test the effect of the three policies mentioned above, all of which are designed to encourage specialization in cattle production. The results suggest that such policies would not be wholly effective without complementary policies which would relieve labor constraints in the harvest and pre-harvest periods and which would preserve the value of forage resources during the rainy season, thus preventing the permanent degradation of the range. One such complementary policy, that of protected forage cultivation, is discussed in the final section of the paper.

Applicability of Results. -- The analysis applies directly to a cross-section of Bush Tuareg mixed farm households in the southern Azawak in a year in which, in addition to the other parameters in the model, the amount and distribution of rainfall was as observed during the survey year. This latter consideration is particularly important, since varying amounts and spatial and temporal patterns of rainfall would alter the labor requirements and possibly the relative profitability of agricultural enterprises. Thus, the model is useful for cross-sectional comparisons, but given the extensive variability of rainfall patterns in the southern pastoral zone, the model could not be used reliably to predict or explain behavior over time.

The model assumes perfect foresight on the part of producers, who base their decision-making on known prices, labor requirements, and risk parameters. In actuality, producers probably select the size and combination of agricultural enterprises on the basis of expectations formulated from experience over a number of years, not simply one year. The following interpretation of the model assumes that producer expectations concerning the parameters of the model did not deviate substantially from estimates of the parameters derived from data collected by the research team during the survey year. Only if it can be assumed that such expectations are constant over time, which is doubtful, could the model be used successfully for intertemporal comparisons. A more realistic formulation, which could explain behavior over time, would be to assume that expectations vary in some predictable fashion based on variations in rainfall patterns. The author hopes to test this formulation in future research.

Monetary Units. -- The unit of account throughout this report is the franc CFA (designated as F CFA), the official currency of much of former French West Africa, including Niger. The franc CFA is supported by the French banking system and guaranteed parity with the French franc at a rate of 100 (CFA) to 1 (French). During the survey year, the official exchange rate for the franc CFA varied from 222 to 246 F CFA per dollar.

Comparison of Production Systems Surveyed

This section of the report compares the agricultural enterprises undertaken by the three major subsamples: Haussa, Bush Tuareg, and Village Tuareg. Although most of the subsequent analysis dwells on Bush Tuareg households, information on other households is presented here by way of contrast since such households do form a significant proportion of the population of the southern pastoral zone, although they are not in the majority. Statistics relevant to the three Fulani households in the survey sample also are presented, but these statistics will not be discussed herein, and the reader is cautioned that such statistics may not be representative of most of the Fulani households in the pastoral zone. In comparing the three

major production systems, the following discussion dwells on labor patterns and availability, land use, livestock management, and the output and consumption of agricultural products.

Labor Patterns and Availability.-- Table 1 presents summary statistics by subsample on labor availability, area planted, and grain and milk production. Labor availability, presented as the number of working resident equivalents, signifies that one household member of at least eight years of age was present in the household for the entire year. Thus, a working household member who was present in the household for only nine of the twelve survey months would register as .75 resident equivalents. The conversion to resident equivalents was found to be desirable since individuals travel extensively in the pastoral zone and there was a great deal of movement into and out of households.

As Table 1 indicates, the twelve households in the Bush Tuareg subsample had, on the average, the greatest number of family members of working age residents in the household. In contrast, Village Tuareg households had the least amount of working age labor available. Ten of the seventeen Village Tuareg households had less than three resident equivalents during the survey year, whereas only four Haussa and four Bush Tuareg households fell within that category. On the average, including children under eight years of age, household size varied among the three subsamples from five to seven resident equivalents of all ages. Haussa households had the greatest number of children under eight years of age in residence.

The outstanding characteristic of the statistics presented in Table 1 is that, as the ranges indicate, the underlying distributions display an enormous degree of dispersion. Curiously, an analysis of the data indicated that variations in grain and milk production are not highly correlated with variations in labor availability. This suggests that other factors, such as access to land and the use of hired labor, must be considered in explaining variations in agricultural production.

The statistics in Table 1 also suggest that Village Tuareg households were not only relatively smaller than households in the other subsamples, but they were also the least successful agricultural producers. They planted

TABLE 1

LABOR AVAILABILITY, AREA PLANTED AND GRAIN AND MILK PRODUCTION[a]

Statistic	Units	Haussa	Village Tuareg	Bush Tuareg	Fulani
Labor Availability	resident equiv./household				
Range		1.37 - 8.33	1.83 - 3.82	1.94 - 7.74	1.89 - 7.66
Mean		3.82	2.74	4.27	4.14
Area Planted	ha /household				
Range		2.29 - 49.62	.82 - 5.31	.96 - 13.90	1.36 - 8.52
Mean		8.67	2.74	5.18	4.25
Grain Production	kg /household				
Range		33 - 2912	0 - 481	0 - 16,250	0 - 104
Mean		580	164	2348	45
Milk Production	liters/household				
Range		0 - 379	0 - 988	70 - 2465	0 - 1045
Mean		56	170	761	599

[a]Data from Appendix IV, Eddy monograph

less land and harvested less grain than either of the two major subsamples. Haussa households planted the greatest land area to grain, but they were not on the average the most successful grain producers. Most of the land planted to grain by Haussa households was upland soil planted to millet. In contrast, most of the area planted by Bush Tuareg households was in the lowlands and was planted to sorghum. Bush Tuareg households were the most successful grain producers, partially because sorghum was a more successful crop than millet during the survey year.

The figures on the following pages show a breakdown for each subsample of the allocation of labor throughout the year by five major activity groupings: crops, livestock, commerce, domestic work, and rest. Labor use in each category is measured by the average number of hours per fortnight (two-week period) allocated to each category by working household members. The total amount of labor available, on the average, for each fortnight is indicated by the top line of each graph. In calculating labor availability, it is assumed that household members will work up to a maximum of twelve hours per day.

Figure 5 gives the breakdown of labor use by Bush Tuareg households. The most noticeable seasonal difference in labor use is the drop in labor allocated to livestock during July and August, which is the growing season for grains. During the same period, labor allocated to crops increases sharply, and household members take less than an average of three hours of rest during the daylight hours of each day. Labor allocated to crops rises again during the harvest season in October, a time when the amount of labor allocated to livestock has also increased relative to the growing season. The total amount of labor available rises slightly during the growing season and the harvest season.

The labor patterns of a representative Bush Tuareg household can be summarized as follows: In the dry season, which runs through the first five months of the year, there are four people of working age present in the household: an adult male and female and a younger girl and boy. The woman and the young girl each spend six hours a day on domestic tasks. The man and the young boy tend the animals for five or six hours of every day, and once a week the entire family visits the weekly market.

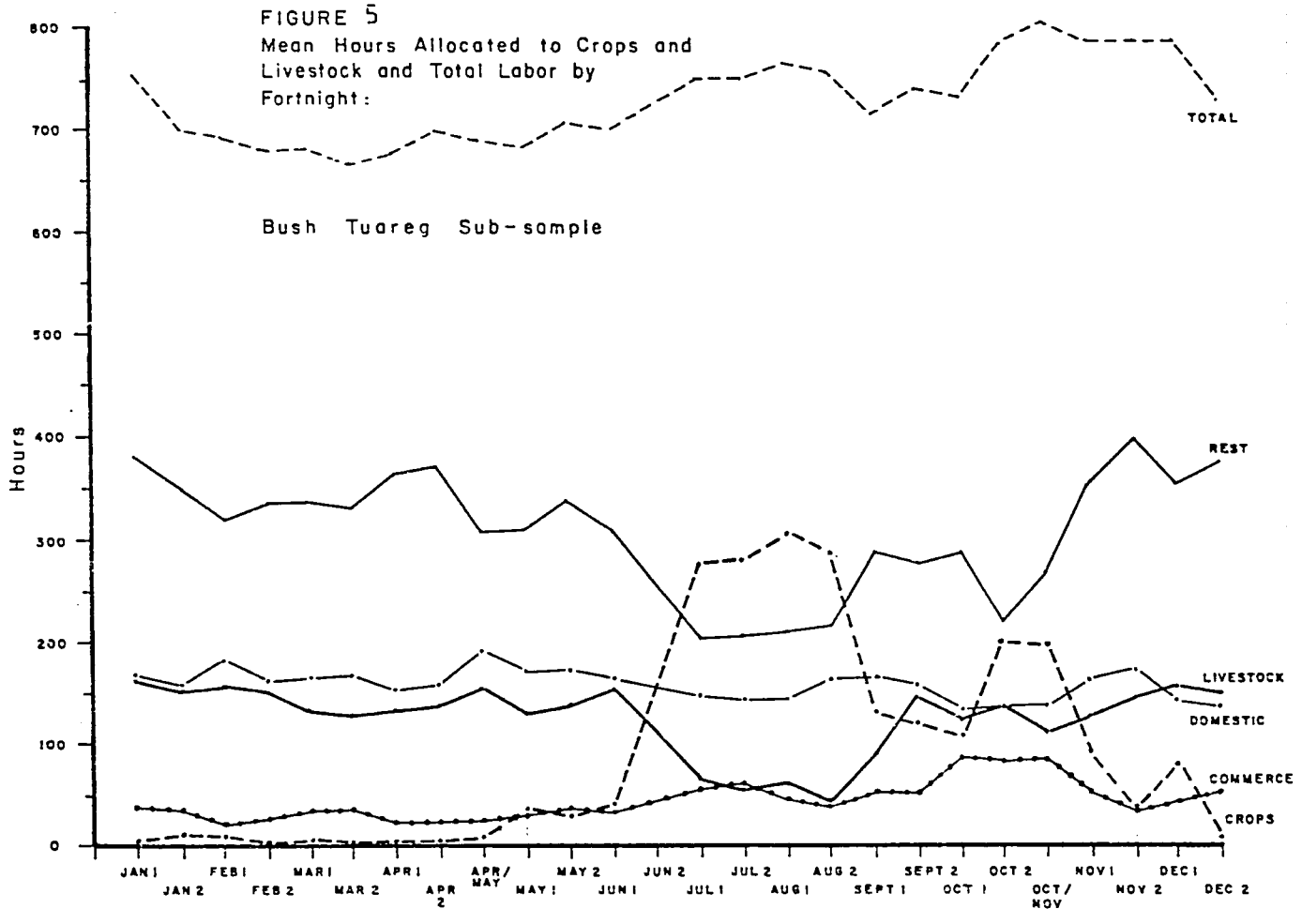


FIGURE 5
Mean Hours Allocated to Crops and Livestock and Total Labor by Fortnight:
Bush Tuareg Sub-sample
Hours
800
700
600
500
400
300
200
100
0
TOTAL
REST
LIVESTOCK
DOMESTIC
COMMERCE
CROPS
JAN 1
JAN 2
FEB 1
FEB 2
MAR 1
MAR 2
APR 1
APR 2
APR/MAY
MAY 1
MAY 2
JUN 1
JUN 2
JUL 1
JUL 2
AUG 1
AUG 2
SEPT 1
SEPT 2
OCT 1
OCT 2
OCT/NOV
NOV 1
NOV 2
DEC 1
DEC 2

Labor in the fields begins in late April, and the entire family devotes correspondingly less time to rest and to the animals. A male family member returns to the household in June as the rains begin and as crop production begins in earnest. During July and August, the animals are left to the young boy, who devotes four hours a day to their care. The women continue with the domestic work, but in addition, they assist the men for two hours a day in the fields, as does the young boy when he is not working with the animals. Each of the men devotes an average of eight hours a day to crop production at this time. This combination of activities leaves just enough time during the daylight hours of each day for the family to eat their meals. In order to free up more time for social activities, the household may hire labor to assist with the work in the grain fields.

After the final weedings are completed in the grain fields in late August, one of the adult household members travels to visit a relative. The adult male devotes more time to assisting the young boy with the animals, since extra care is required at this time in order to keep the animals away from the enticing heads of grain.

As the harvest begins, each of two household members must continue to spend six hours per day with the animals in order to keep them out of the fields, and each of the two women still are confined to six hours a day of domestic chores. Commercial activities take up another three hours a day of the family's available labor time in addition to the time spent in the weekly market, since the supplemental income derived from crafts is required to finance grain purchases at a time when stocks are low. Each family member requires three hours each day to eat his meals. This leaves approximately fourteen hours each day for harvesting from the household's entire available stock of labor of sixty hours per day. In some cases, that fourteen hours - amounting to only two or three hours labor per day per working household member - is not enough labor to evacuate the grain to storage areas before animals, birds or rodents reach it. The problem is further exacerbated by herds returning from the north who are anxious to rejoin their dry season pastures. By November, the harvest is completed, and as visitors leave the household in late December, the household returns to its more regular dry season labor schedule.

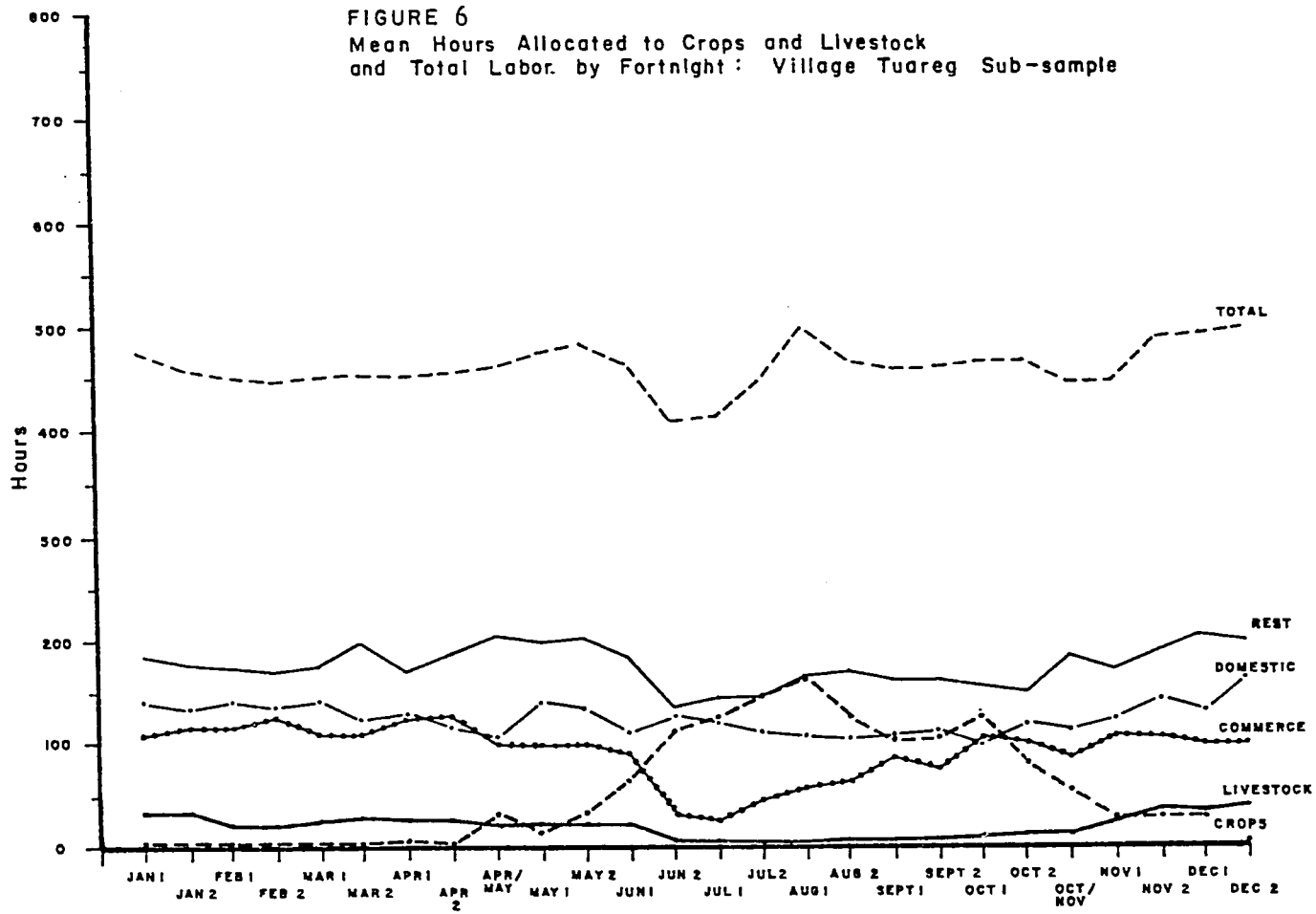
Figure 6 indicates the patterns of labor allocation for the average Village Tuareg household. The most obvious difference between this and the previous graph is that, relative to Bush Tuareg households, Village Tuareg households have much less available labor. An additional difference is that the average Village Tuareg household devotes more time to commerce, which includes time spent on crafts, on sales, and on wage labor. Time devoted to commerce declines as time devoted to crop production increases during the growing season, indicating the same sort of trade-off as exists between crop and livestock activities at that time among Bush Tuareg households.

Village Tuareg households devoted very little time to livestock enterprises. Only three of the seventeen households in the subsample owned and managed animals throughout the survey year. These households also devoted relatively little time to crop production. The main source of their livelihood was income derived from sales of crafts and services. Thus, aside from commerce and domestic activities, little time was left over for agricultural enterprises.

Labor allocation in a representative Village Tuareg household may be described as follows. A typical household has five full-time members: an elder man and woman, teenage child, and two younger children. During the dry season, which spans the first five months of the year, the woman and the teenage child each spend four to five hours per day on domestic chores. The man spends two hours each day tending animals owned by wealthier village residents. During this period, the man and woman each spend four hours of every day working as hired laborers, tending small stands in the marketplace, or making crafts for sale to supplement the household's income.

In late April, the woman takes time away from domestic work to assist the man in planting the small millet field which has been loaned to them by more wealthy Haussa village residents. As the rains begin in June and crop production activities pick up, time allocated to commerce declines and remains at a low level until late July. From late July through August, the man undertakes work in the fields owned by Haussa village residents while continuing to work on his own fields. In October, as the harvests come in, the woman once again takes time away from domestic work to assist with the transport of the grain. While he is harvesting his own fields, the man de-

FIGURE 6
Mean Hours Allocated to Crops and Livestock
and Total Labor by Fortnight: Village Tuareg Sub-sample



votes more time to commerce during a period when the markets are active. As the harvest is completed in November, the dry season work patterns are resumed.

Figure 7 illustrates the average labor patterns of Haussa households. The distinctive feature of the Haussa production system as regards the labor input is that seasonal crop production activities do not detract significantly from time spent on any other productive work category. This is because the hiring of labor relieves any possible constraint due to crop production activities during the June through August period. This is evidenced by the sharp increase in total labor availability during that period. During July, households in the Haussa subsample hired an average of twenty hours per week of labor services. The amount of labor hired rose to seventy-five hours per week during August, which was the month when the maximum amount of rain fell and crop weeding labor requirements were at their peak. The household also was assisted during the crop cycle by the return of the young men who had sought work in urban centers during the dry season. Furthermore, the increase in water sources during the rainy season enabled household members to spend less time on domestic work and more time assisting laborers in the fields. The combined additions to the household labor force provided sufficient labor for crop production so that other activities could continue uninterrupted. Working household members were able to engage in non-productive social activities for an average of at least 4.5 of the twelve daylight hours of every day throughout the growing season.

Having assisted their families with the most arduous crop production tasks (weeding), the young men began to leave the village again in early October as the harvest period started. Haussa households also reduced the amount of labor hired at this time. There was a resultant drop in labor availability, but during the survey year, Haussa households had an average sufficient labor to cover harvest activities and the increase in commercial activities prompted by the active November markets without hiring additional labor or reducing rest activities below a level which allowed for an average of over four hours of rest daily per working household member.

Figure 8 indicates the percentage of available labor allocated to agricultural production in each fortnight of the year by each subsample. As

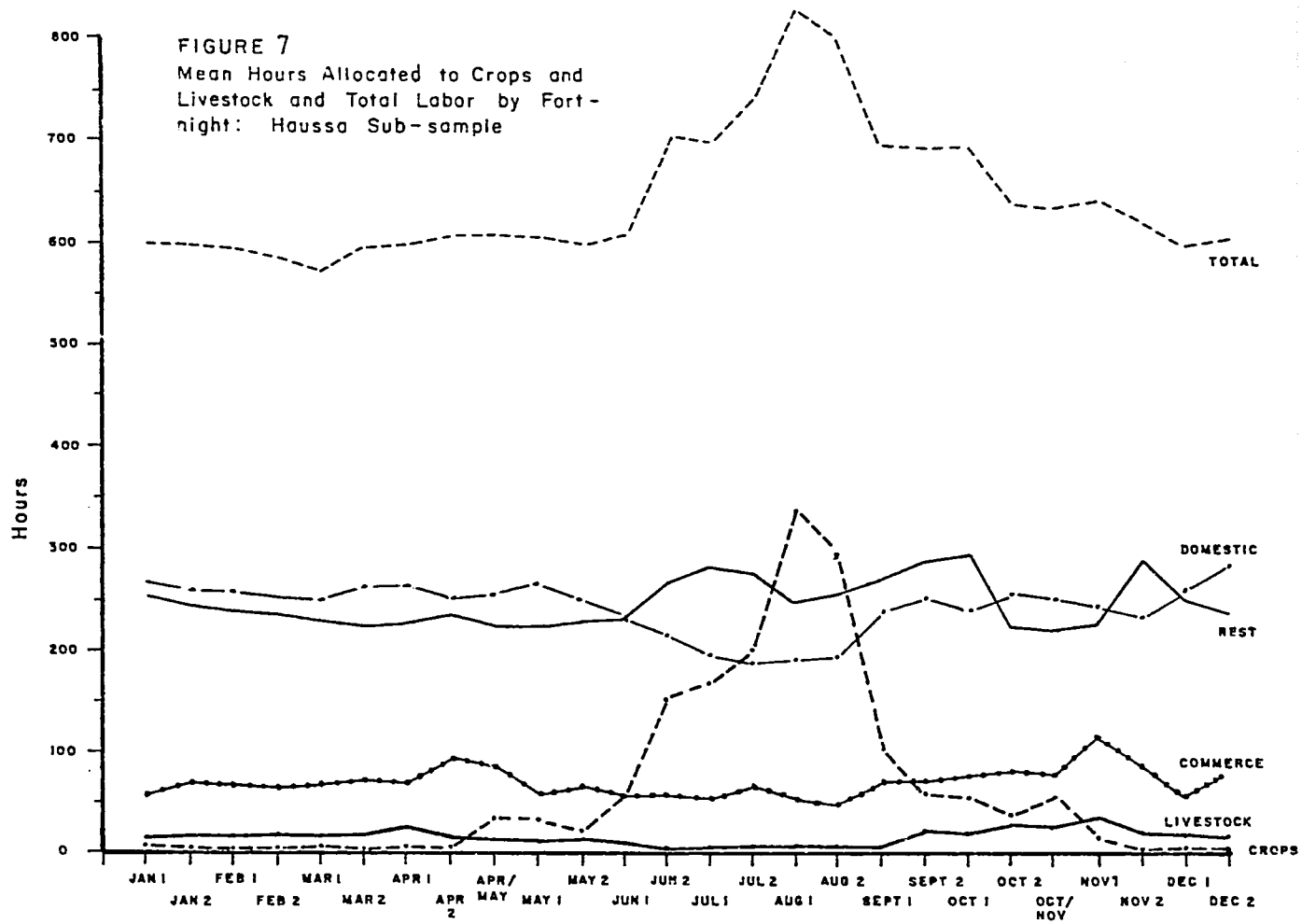
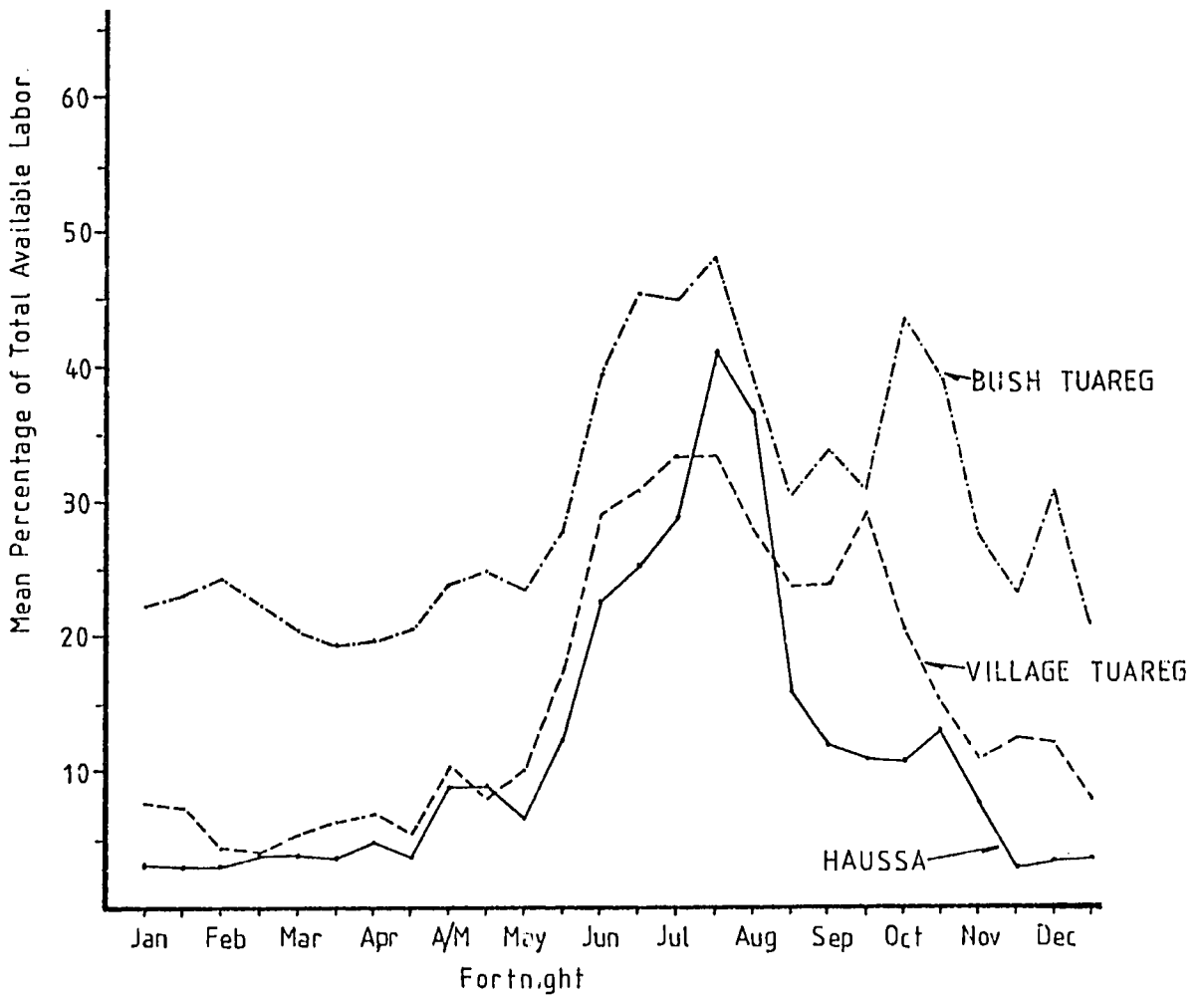


FIGURE 7
Mean Hours Allocated to Crops and Livestock and Total Labor by Fortnight: Haussa Sub-sample

FIGURE 8 : Percentage Allocation of Labor to Agricultural Production



suggested by the above analysis, activities related to agricultural production were most important among households in the Bush Tuareg subsample. The average Bush Tuareg household devoted between 20 and 50 percent of available labor to agricultural production throughout the year. This was not the case among village residents (Haussa and Village Tuareg subsamples) who devoted less than 10 percent of available household labor to agricultural production outside of the June to October crop cycle. This is consistent with the description of Bush Tuareg households as subsistence producers who devoted more time to agricultural enterprises, in contrast to Village Tuareg and Haussa households, whose members devoted relatively more time to commerce and relatively less to either crop or livestock production.

Land Use and Grain Output. -- The only officially recognized form of private ownership of land by the individual household in the southern pastoral zone is the right of the grain producer to recover compensation for damages inflicted by herds trespassing on plots planted to grain. No similar individual rights in land are extended to the livestock producer. The land input to livestock production is a public resource and pasture is therefore available on a "first come, first served" basis. Despite a 1961 law which was intended to discourage grain production in the pastoral zone, grain producers still are able to obtain private rights in the land by clearing a plot and planting it to grain. The effect of these policies is to encourage the individual to make improvements in the land which enhance its quality as an input to grain production, but no similar incentive exists for the individual to improve the land for use as an input to livestock production. Furthermore, the recognition of private property rights in land allocated to grain production, but not in land allocated to livestock production, probably encourages the expansion of grain cultivation.

Since land available as an input to livestock production is open to the public, it is difficult to estimate the quantity of the land input to livestock enterprises. However, the research team did obtain measurements of all plots planted to grain by sample households during the survey year. Each household planted from one to four plots, and each plot contained millet, sorghum, or some combination of the two. In addition to the two

major grain types, some households also intercropped cowpeas or gumbo (okra). This was particularly true of households in the Haussa subsample, but intercropping was not practiced by Bush Tuareg households. Since the quantities and value of the cowpea and gumbo harvests were insignificant relative to the grain harvest during the survey year, the following analysis considers only the production of the two major grain types.

Production statistics for millet and sorghum are presented in Tables 2 and 3. Millet was grown as a rain-fed crop and was planted primarily in upland, sandy soils. In contrast, most of the sorghum crop was planted in the alluvial, predominantly clay soils in the runoff channels which carry water from the surrounding hills. The tables indicate that millet cultivation was less labor-intensive than sorghum. For all three major subsamples, the mean number of hours applied per hectare to millet fields was approximately half the per-hectare labor input to sorghum fields.

Millet production per household varied widely. During the survey year, households in the Haussa subsample appeared to be more successful millet producers than other households, particularly those of the Bush Tuareg subsample. Mean millet production per Haussa household was 189 kilograms, whereas only one of the twelve Bush Tuareg households harvested any millet, and that harvest amounted to only 90 kilograms.

Although Haussa households appeared to be more successful millet producers, the statistics in Table 2 suggest that Bush Tuareg households were the most successful sorghum producers. The twelve households in that subsample accounted for 78 percent of total sorghum production by the forty-five sample households. One Bush Tuareg household produced an extraordinary harvest of over sixteen metric tons of sorghum. Average sorghum production among the other nine households in that subsample who had some harvest was 1,315 kilograms. This was more than twice the average production by Haussa sorghum-producing households and ten times the average production by the Village Tuareg households which planted sorghum.

The median area planted per household to all crops was approximately three hectares, and the median area per plot was between 1.0 and 1.5 hectares. This excludes four households which planted over ten hectares each; these four households included three successful Haussa merchants and a Tuareg camp chief.

TABLE 2

MILLET PRODUCTION STATISTICS BY SUBSAMPLE

Statistic (Per Household)		Haussa (n=16)	Subsample Village Tuareg (n=17)	Bush Tuareg (n=12)
Total Area Planted (Ha.)	Mean	7.40	2.15	2.99
	Range	.74 - 47.30	.19 - 4.05	.32 - 6.88
Total Labor (Hours)	Mean	1224	833	498
	Range	408 - 3020	36 - 2467	136 - 1097
Total Grain Produced (Kg.)	Mean	189	73	7
	Range	0 - 604	0 - 248	0 - 90
Hours/Ha.	Mean	258	436	212
	Range	64 - 589	60 - 1132	54 - 734
Kg./Hour	Mean	.13	.10	.01
	Range	.00 - .34	.00 - .29	.00 - .08
Kg./Ha.	Mean	46	39	1
	Range	0 - 136	0 - 159	0 - 17

SOURCE: Appendix V, Labor and Land Use on Mixed Farms in the Pastoral Zone of Niger, Center for Research on Economic Development and USAID, 1979.

TABLE 3

SORGHUM PRODUCTION STATISTICS BY SUBSAMPLE[a]

Statistic (Per Household)		Subsample: Haussa (n=14)	Village Tuareg (n=12)	Bush Tuareg (n=12)
Total Area Planted (ha.)	Mean	1.38	.75	2.26
	Range	.20 - 3.34	.13 - 1.68	.31 - 7.90
Total Labor (Hours)	Mean	579	544	1592
	Range	163 - 1365	24 - 1821	297 - 3670
Total Grain Produced (Kg.)	Mean	444	128	2341
	Range	0 - 2066	0 - 435	0 - 16250
Hours/Ha.	Mean	413	765	895
	Range	105 - 792	154 - 1917	412 - 2137
Kg./Hour	Mean	1.08	.22	1.02
	Range	.59 - 1.51	.00 - .66	.00 - 4.43
Kg./Ha.	Mean	373	146	731
	Range	0 - 637	0 - 345	0 - 2057

SOURC ›pendix V, Labor and Land Use on Mixed Farms in the Pastoral Zone of Niger, Center for Research on Economic Development and USAID, 1979.

[a]Statistics based on data for those households which cultivated sorghum, as indicated by the subsample size.

It is possible that the four households planting abnormally large plots were encouraged to do so by the prevailing system of land tenure. As mentioned above, individual property rights vested when an area was cleared and planted to grain. Such rights enabled the owner to bring suit against the herder whose animals had encroached upon the field. These rights could be defeated only by failure to plant the field in subsequent years.

Crop damage suits were brought before the local Haussa village chief, a forum which was generally unfavorable to the herder. If the Haussa village chief finds for the grain producer, as is the outcome in most such cases, he then awards damages based on the number and type of animals that are found to have entered the field and whether the animals are found to have entered during the daytime or at night. Judgments are enforced by armed nomad guards who are stationed in villages such as Kao during the growing season.

When a satisfactory conclusion is not reached at the village level, the suit may be referred to the office of the Sous-Préfet, or regional governor. The influence of Haussa merchants with the regional administration and the predominance of Haussa civil servants in the government also provides a favorable atmosphere for the crop producer in the event of a referral.

Property laws in Niger, as they were explained to this author by a local government official, also recognize a more permanent interest in land than that mentioned above, once a household has planted a given plot to grain for three consecutive years. The ability to acquire a more permanent vested interest in land merely by continuing to plant grain is an additional incentive to continue grain cultivation, even though the producer may have an alternative source of income from trade which makes the cultivation of grain for subsistence unnecessary. The rights accompanying this interest may be defeated by failure to plant during each successive growing season, but there is no requirement that the individual asserting these rights continue to cultivate the entire field through to harvest in order to maintain his rights to the entire parcel. The condition that the owner continue to plant may be fulfilled by hiring laborers to plant and weed for the first few months of the season, thus avoiding the need to allocate

household labor to these tasks. Then, once the plants have sprouted, the farmer can abandon the field altogether while maintaining his interest in the land and his right to an action for damages if trespassing herds encroach upon it.

The combined effect of these practices is to encourage the expansion of grain cultivation without stimulating either grain or livestock producers to improve the land or to prevent environmental degradation. Furthermore, the current system for enforcing the limited private property rights that exist appears to favor the grain producer at the expense of the livestock producer. These problems will be discussed further at the conclusion of this paper.

Livestock Output. -- Several types of animals are raised in the southern pastoral zone, including goats, cattle, donkeys, horses, camels and sheep. In addition, many families living in villages raise poultry as a supplemental source of protein. Poultry production was not a common activity among households living outside of the village.

Donkeys are used as work animals, primarily for hauling water, grain and firewood. In addition, they are the southern pastoral zone's most popular form of personal transport. They are considered to be versatile and hardy animals, withstanding the harshest of environments. Donkeys are particularly indispensable to households living outside of the village, such as those of the Bush Tuareg subsample. Accordingly, within the survey sample, donkey ownership was concentrated among Bush Tuareg households.

Camels also are used for transport, but they are more expensive animals, and their ownership is the prerogative of wealthier households. Camels also are raised for their milk. Although not as hardy as donkeys, they do have a wider range of grazing options in that they can browse the tops of trees as well as low brush.

Horses, like camels, are a more prestigious form of personal transport reserved for wealthier households. Only the six most affluent households in the survey sample owned horses.

Among sample households, sheep were raised primarily for meat. Most often they were raised for slaughter at special occasions, such as marriages, baptisms, and other festivals. Sheep production was most concentrated

among members of the Haussa subsample. None of the sheep herds held by sample households included more than ten head.

Goats were the animals most commonly held in sample members' herds. In terms of number of head, they far outnumbered any other animal type in all but the smallest of herds managed by sample households. There are several reasons why sample households -- and Tuareg households in particular -- preferred goats over other animal types: like donkeys, goats are resistant to climate stress; goats are easy to manage and entail less risk than the larger animals; and goats are less expensive to acquire. Furthermore, the rapid growth rate of the herd relative to other animal types means that less time is required to build up a herd which is of sufficient size to provide milk and meat for the household. In the survey sample, goats were held by all of the Tuareg households which owned any animals. Goats were the primary source of milk and meat for these households.

Cattle were the second most important source of milk for household consumption. However, less than one-third of the households in the survey sample owned or managed cattle at some point during the survey year, and the largest of these herds was only ten head. Although cattle do supply substantial quantities of milk, they are more costly animals, and greater risk is involved in their management. For this reason, Tuareg households prefer to build up and maintain a subsistence herd of at least twenty goats before diversifying into cattle production.

Of the types of animals owned by sample members, the remainder of this paper concentrates on goats and cattle, since these animals figured most prominently in sample members' herds. These two animal types were especially important among the herds of Bush Tuareg mixed farmers, the target group of the linear programming analysis. In addition to their importance in numbers, cattle and goats provided most of the milk and meat consumed by sample households. Although camels were an alternative source of milk, only five sample households were engaged in camel production during the survey year. Sheep were an alternative source of meat, but, as indicated above, their ownership was restricted to Haussa households, which had small herds held mainly for slaughter at festivals.

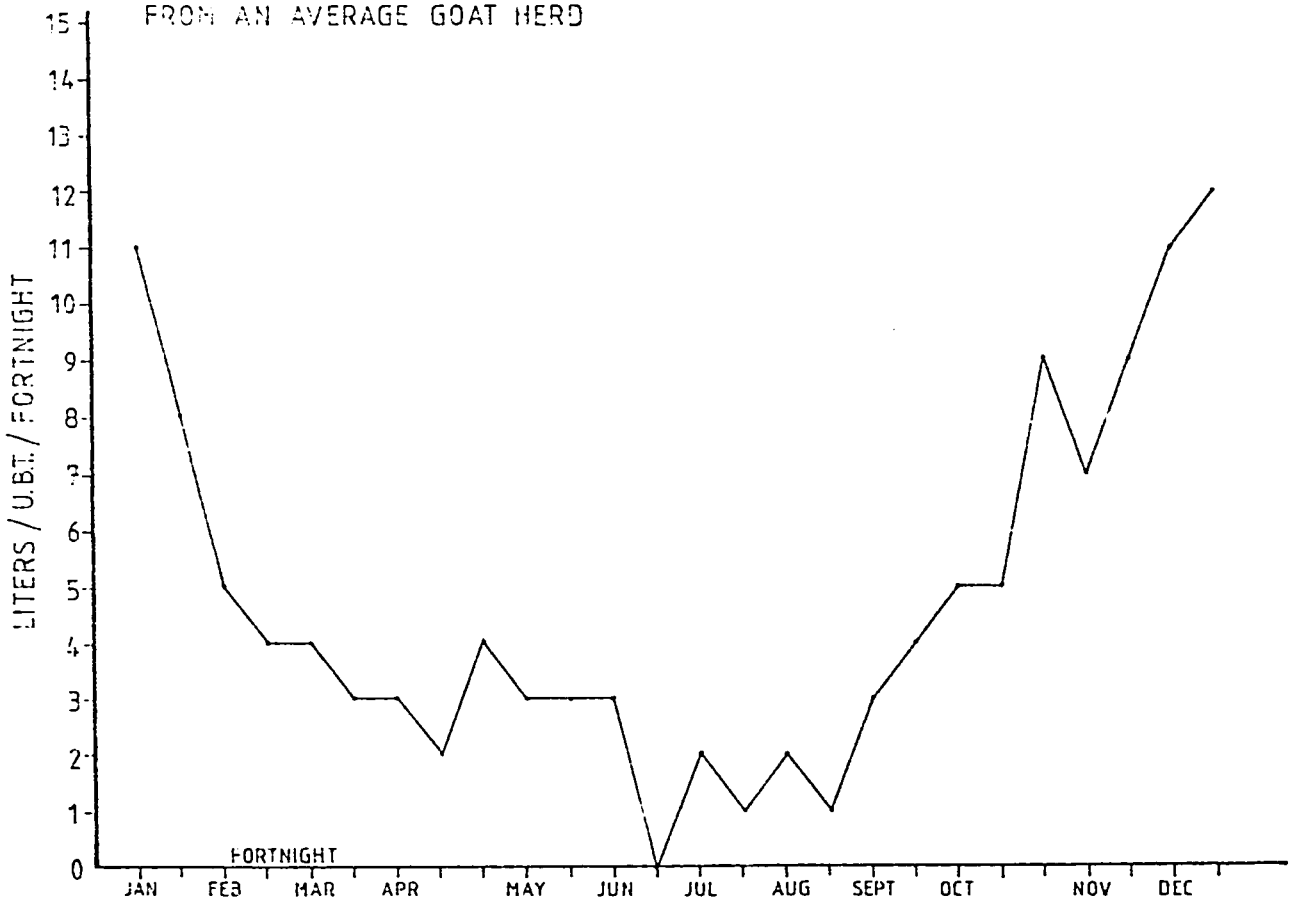
For the purposes of the linear programming analysis, two livestock production activities are considered. The first involves raising goats alone, and the second combines cattle with goats. Cattle production is not considered as an independent activity, since all sample households which produced cattle also produced goats, and the labor inputs to the production of one animal type were inseparable from inputs to the production of the other.

A standard animal unit was used as a basis for comparing the goat herd and the combined herd in terms of labor requirements and output. The unit employed was the Tropical Bovine Unit (Unité Bovine Tropicale, or U.B.T.), which is roughly equivalent to an animal with a live weight of 250 kilograms. Thus, either 5 goats or 1.2 head of cattle constitute one U.B.T.

For sample households, milk production was the most important output from livestock enterprises, and in terms of milk production, the diversified herd of cattle and goats has several advantages over a herd containing goats alone. The average patterns of milk production per fortnight and per animal unit for a sample of four goat herds and a sample of four mixed herds of cattle and goats are shown in Figures 9 and 10. Milk production for the average goat herd is lowest during the rainy season (June through September). This is because females come into heat at the beginning of the rainy season, kid at the end of the rainy season, and produce milk until the onset of the hot, dry season (late February). Although this reproductive cycle is convenient for survival of the young, the timing of milk output provides a complementary food source to grain when it is least needed. Most females reach the peak of their lactation cycle just at the end of the grain harvests, when grain is most plentiful. However, during the growing season, when grain stocks are low and energy expenditure by the household is high, milk production from the goat herd drops to its annual low.

In contrast to this pattern, the mixed herd of cattle and goats produces more milk per animal unit throughout the year and reaches peak production during the time when milk is most needed as a complementary food source. During August, when grain stocks are lowest and the amount of human energy required for crop production is highest, a mixed herd consisting of seven animal units (eighteen goats and four head of cattle)

FIGURE 9 :
MILK PRODUCTION PER ANIMAL UNIT
FROM AN AVERAGE GOAT HERD



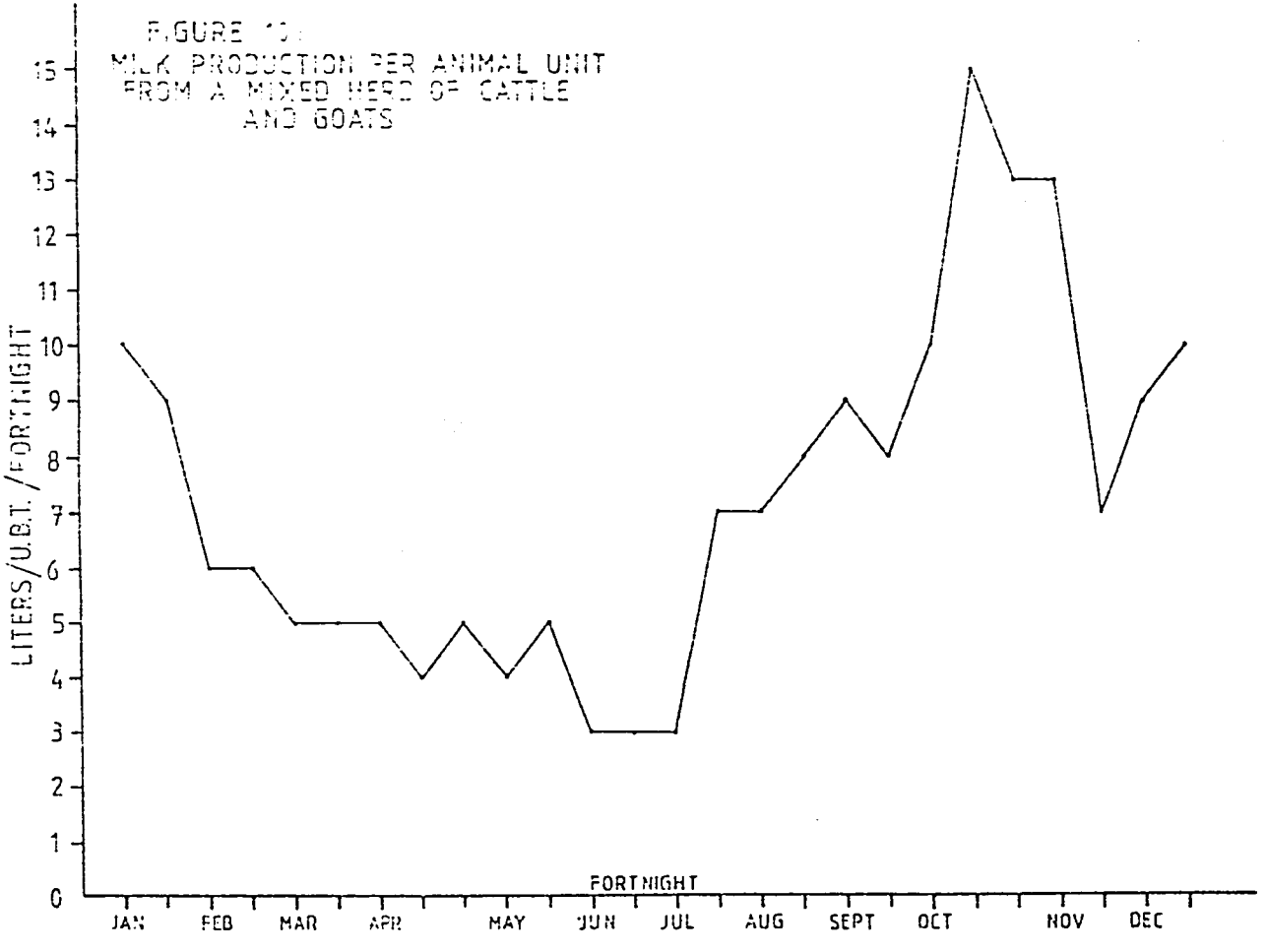


FIGURE 10:
MILK PRODUCTION PER ANIMAL UNIT
FROM A MIXED HERD OF CATTLE
AND GOATS
LITERS/U.B.T./FORTNIGHT
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
FORTNIGHT
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEPT
OCT
NOV
DEC

would provide at least three liters of milk per day to the household. Since the goats come into milk as milk production from the cattle component of the herd begins to drop off, the mixed herd could provide more than three liters per day to the household for at least half the year (mid-July to mid-January).

In contrast, a comparable level of production could be sustained by a herd of seven animal units of goats (thirty-five goats) during only three months of the year (November through January). Furthermore, the total amount of milk output from the mixed herd is approximately 50 percent greater per animal unit than that from the goat herd. Average annual milk production from the four mixed herds of cattle and goats was 189 liters, whereas the four herds containing only goats produced an average of 124 liters per animal unit.

In order to estimate the producer's expected return to his annual labor input to livestock production, two types of "output" must be evaluated in addition to the value of milk output. The first is the appreciation in value of animals held in the herd. The second is the value of young born alive into the herd during the year and surviving at the end of the year. The result is a more accurate measure of the expected return to labor than would be provided by profits from animal sales alone.

The appreciation in value of an animal held in the herd is measured by the change in the market price of the animal as a result of its growing one year older. The prices used to evaluate this component of livestock output are discussed in subsequent sections of this paper. To estimate the expected return, the gain represented by change in price must be discounted by the risk that the animal will die or otherwise be lost from the herd during the year in question. Similarly, the value of young born into the herd must be discounted by probabilities of survival.

The results for the two types of livestock production activities (goats and cattle combined with goats) are presented in Tables 4 and 5 . The cost per animal unit of salt purchased during the year has been deducted, salt having been the only purchased input of significant magnitude. The results show that the expected return from holding animals in the herd is much lower than either the value of surviving young or the

TABLE 4

EXPECTED VALUE OF OUTPUT PER U.B.T. OF GOATS

Item	F CFA
Value Added by Animals Held in Herd:	
Males	1,076
Females	1,122
Total	2,198
Value Added by Surviving Young Born into Herd	4,176
Value of Milk Production	6,200
Cash Costs (Salt Purchases)	-250
TOTAL	12,324

TABLE 5

EXPECTED VALUE OF OUTPUT PER U.B.T. FROM THE COMBINED HERD OF CATTLE AND GOATS

Item		F CFA
Value Added by Cattle Held in the Herd		
Males	975	
Females	1,468	
Total		2,443
Value Added by Surviving Calves Born into the Herd		1,574
Value Added by Goats Held in the Herd		
Males	538	
Females	561	
Total		1,099
Value Added by Surviving Kids Born into the Herd		2,088
Value of Milk Production		9,450
Cash Costs (Salt Purchases)		-250
TOTAL		16,404

value of milk production. The low annual return to animals held is due to the risk parameters, as reflected in the survival probabilities. This suggests that improvements aimed at decreasing risk might have an important impact on the relative profitability of livestock production.

For either activity, milk production accounts for over half of the expected value of output net of cash costs. This reinforces the claims of sample households that milk was the most important output from livestock enterprises. It also suggests that technological improvements which affect milk production would have a greater impact on the relative profitability of livestock enterprises than would marketing interventions which affect the structure of animal prices. The effects of these and other policy initiatives will be examined using the linear programming model.

Consumption of Grain and Livestock Products.-- A summary of the estimated per capita consumption of the major grains and livestock products is provided in Table 6 . Calorie requirements are based on the age and sex composition of the average household in each subsample. As indicated, consumption of the two major grains fulfills more than half of the requirement for each subsample. Given the inability of the present distribution system to provide markets in the southern pastoral zone with a steady supply of high-quality grain, the importance of grain in the household diet is an additional incentive to continue grain cultivation.

The high proportion of calorie requirements derived from millet and sorghum consumption by Haussa households is somewhat disturbing. There are several possible explanations. First, the number of people consuming grain prepared by Haussa households may have been underestimated in that the presence of guests who visited the household only at mealtime was not recorded during the survey. Second, Haussa households may have consciously exaggerated grain consumption in the hope of obtaining additional food aid from government programs. Third, it could be that meat, milk, and sugar consumption were much more important sources of calories and protein among Tuareg households than among Haussa households. Tea and

TABLE 6

CONSUMPTION OF GRAIN AND LIVESTOCK PRODUCTS

	Estimated Daily Per Capita Consumption								
	Grain				Livestock Products				
Subsample	Millet (kg)	Sorghum (kg)	Total Caloric Value	Proportion of Requirement (%)	Meat (g.)	Milk (ml)	Total Caloric Value	Proportion of Requirement (%)	Total Contribution to Calorie Requirements (%)[a]
Haussa	.99	.26	2549	99	39	84	110	4	103
Village Tuareg	.44	.31	1482	58	21	213	181	7	65
Bush Tuareg	.28	.48	1450	51	13	351	272	10	61

[a]Proportion of calorie requirements derived from grain and livestock Products.

sugar consumption probably provided most of the calories required by Tuareg households beyond those supplied by the consumption of grain and livestock products. Therefore, the high proportion of calories derived from grain consumption by Haussa households may indicate that such households had fewer and less important alternative sources of calories other than grain.

Livestock products definitely were a more important element of the household diet among Tuareg sample households than among households in the Haussa subsample. Bush Tuareg households in particular consumed an average of more than four times the daily per capita consumption of milk by Haussa households. On the other hand, Haussa households consumed an average of three times as much meat per capita as did Bush Tuareg households, but the quantity of meat consumed in general was quite small relative to milk consumpiton. This was particularly true of Tuareg households, which further corroborates the notion that animals that are held in Tuareg herds are kept primarily for their milk rather than for their meat.

Relative Ability of Production Systems Surveyed to Expand Cattle Production.-- As is apparent from the data presented in this section, there was a great deal of variation among households within each subsample. However, it is possible to generalize concerning the relative ability to expand cattle production. Of the three systems surveyed, those households classified as Bush Tuareg appear to have the greatest immediate interest in expanding self-managed herds. Relatively more of their income and food needs are derived from livestock production, in which all such households are currently engaged.

In contrast, Haussa households appear to be reluctant to rely on cattle, or livestock in general, as anything but a supplemental source of food and income, although they do see cattle as a preferred form of investment. However, even when acquired as an investment, Haussa households rarely manage the animals themselves and prefer instead to confide them to hired herders who do not live in the immediate vicinity of the household's abode.

Although Village Tuareg households may wish to join their Bush Tuareg neighbors tending cattle outside of the village, most households currently are unable to do so. They presently eke out an existence based on income derived from wage labor and small-scale retail trade, supplemented by grain produced on sub-marginal fields. Whenever some of their income can be set aside after fulfilling their immediate needs, they invest in small ruminants, but neither their small ruminant herds nor their other assets have expanded to the point where they could reasonably consider managing large ruminants such as cattle. The requisite initial investment, the time required to manage the cattle herd, and the risk involved currently are prohibitive for such households.

Thus, of the pastoral zone mixed farming systems which were considered by the survey, the Bush Tuareg system is the most likely to benefit directly from expanded cattle production. For this reason, as well as other reasons mentioned in this paper, the detailed analysis of alternative agricultural development policies is confined to the Bush Tuareg group.

Average Seasonal Labor Requirements of Bush Tuareg Agricultural Enterprises

This section describes the labor requirements of the six agricultural enterprises included in the linear programming analysis of the section which follows. These include: millet production, three sorghum production technologies with varying returns to land, goat production, and the production of goats combined with cattle.

Labor requirements are based on the average hours allocated to each by the groups of households defined below. For the four grain enterprises, labor requirements are measured in hours per hectare for each fortnight. To elaborate on the type of work undertaken within each fortnight, labor allocated to each grain production activity has been divided into five work categories: land preparation, planting, weeding, guarding the fields, and harvesting.

The average labor requirements for the two livestock enterprises are measured in hours per animal unit (U.B.T.). Once again, to illustrate

the nature of the work, labor allocated to each of the two enterprises has been further divided into three work categories: pasture (grazing), watering, and milking.

As part of the linear programming analysis of the following section, it is assumed that labor requirements per hectare and per animal unit are fixed in each fortnight. This assumption is justified for the livestock production activities in that grazing, milking, and watering the animals must be carried out on a daily basis. It is also justified for the grain production activities, in that the timing of work associated with grain production is highly dependent on rainfall patterns. Thus, for a given temporal distribution of rainfall, labor requirements are fairly inflexible between fortnights.

Along the same lines, it is important to remember that the labor requirements specified below are strictly valid only for a given area in a given year. This is because changes in rainfall patterns over space and time would alter the labor requirements and the relative profitability of the various activities. Thus, the results given by the model described in the following section must be interpreted in light of rainfall patterns during the survey year. As indicated in the first section of this paper, rainfall patterns at the research site during the survey year were unusual because heavy rains fell late into the year, producing a second sorghum harvest, and there was a thirty-day drought during the early part of the growing season which crippled the millet crop.

Millet.-- The labor requirements of the millet technology included in the model are based on the average hours per hectare devoted to millet by the households in the Haussa subsample. The Haussa millet technology was selected, since it was the most productive of the millet technologies observed among the three production systems. Since only one Bush Tuareg household was able to produce any millet at all during the survey year, the observed Bush Tuareg millet technology could not provide an adequate explanation of why Bush Tuareg households engaged in millet enterprises. Thus, the selection of the Haussa millet technology is predicated on the assumption that in making planting decisions for the coming crop cycle,

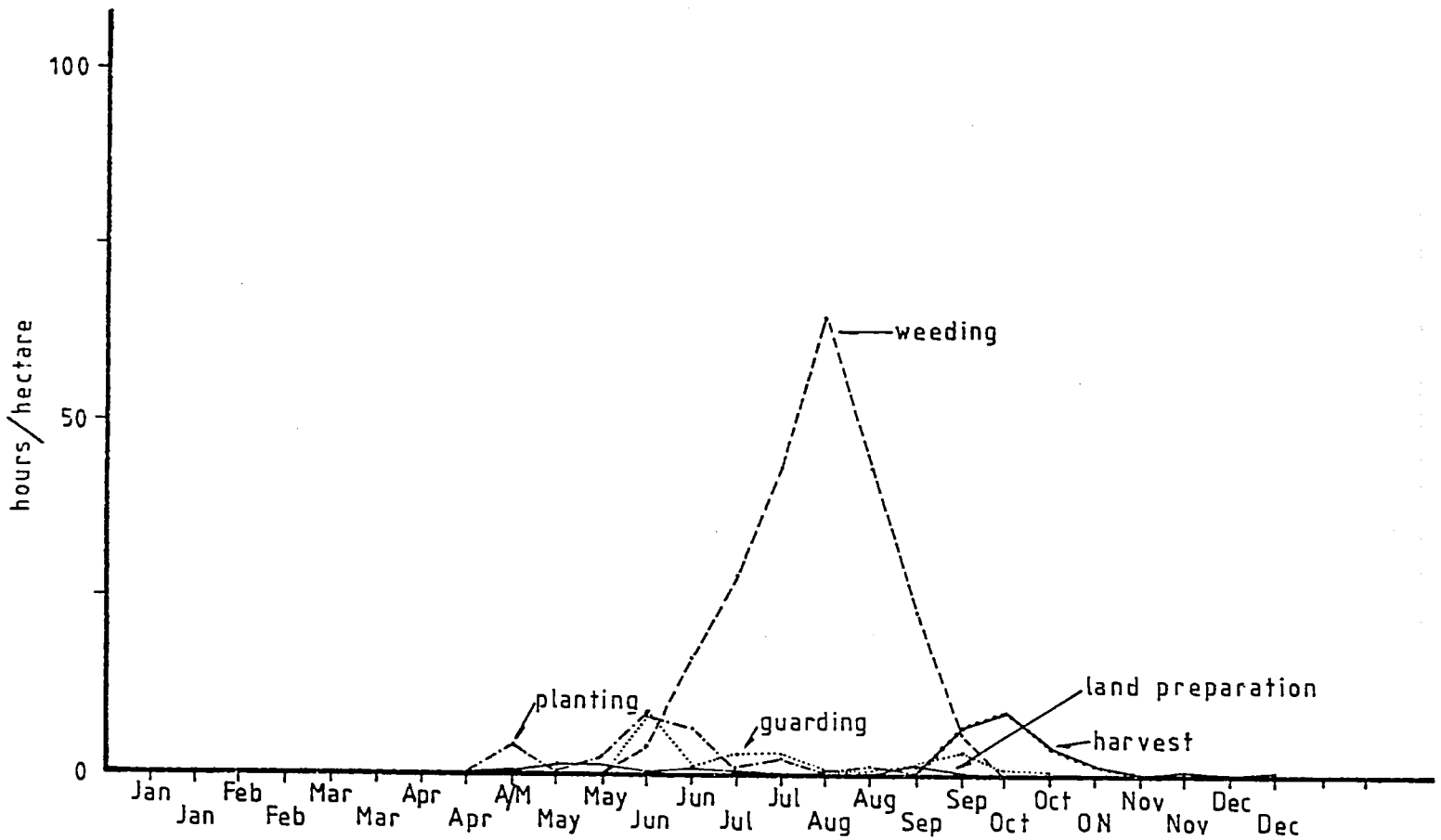
Bush Tuareg households strive to emulate the best locally available technology for any particular enterprise. Indeed, this is the way in which sample members themselves characterized their decision-making: Tuareg households engaged in millet production under the assumption that they would be able to achieve the yeilds obtained by relatively more successful Haussa millet producers. For similar reasons, the most productive sorghum technologies have been selected for inclusion in the model, these being the technologies adopted by Bush Tuareg households during the survey year.

Average labor requirements for each work category in each fortnight are indicated in Figure 11 . As the graph suggests, labor inputs to millet production were concentrated in the June through October period, which is the rainy season. The major activity during that period was weeding, which was probably the most critical task and certainly the most demanding physically. Haussa households met the weeding labor requirement by hiring additional labor, particularly during August, the month of heaviest rainfall. The hiring of labor enabled Huassa producers to spend roughly equal amounts of time per hectare on weeding millet and sorghum fields during the critical period of heavy rainfall.

Discretionary income derived from sales of livestock and livestock products contributed to the ability to hire labor during this period. Hired labor accounted for one-third of the total labor allocated to weeding grain fields by the fourteen sample households which produced both large and small ruminants. In contrast, in seventeen sample households which had no animals, hired laborers contributed only 5 percent of total labor allocated to weeding. For some Tuareg households, the lack of discretionary income with which to hire labor forced them to choose between weeding millet or sorghum fields during the critical period of heavy rainfall. The resulting concentration of weeding labor on sorghum fields obviously contributed to the failure of the millet crop for these households.

Millet was grown mostly on upland, sandy soils for which very little preparation was required prior to planting. The first planting took place in early May, before the rains began. Fields were subsequently replanted as necessary during the early part of the rainy season.

FIGURE 11: Agricultural Calendar for Millet: Haussa Sub-sample



Guarding the millet fields, like land preparation, occupied relatively little time. Most of the labor allocated to guarding the fields was intended to protect the crop from herds in transit through the area. Thus, fields had to be guarded at the beginning and end of the rainy season when herds were in transit to and from northern pastures.

The harvest began in late September and continued through October. Since the herds of nomadic livestock producers were returning from northern pastures during this period, the ripened grain had to be evacuated rapidly to storage areas to avoid damage to the crop. Despite this time constraint, neither the harvesting activities nor any of the other three activities mentioned above constituted as large a proportion of the total labor requirement of the millet enterprise as did labor required for weeding during the rainy season.

Sorghum.-- The labor requirements of the three sorghum technologies included in the model are based on the average hours per hectare devoted to sorghum in each fortnight by each of three groups of households within the Bush Tuareg subsample. The three groups were distinguished on the basis of varying yields (averages of 350, 850 and 1,160 kg /ha). The average labor requirements, broken down by activity, for the two groups achieving greater per hectare yields are illustrated in Figures 12 and 13.

The most distinctive difference between the labor requirements for sorghum and those for millet is that sorghum is a much more labor-intensive enterprise, requiring a greater labor input per hectare for all five work categories. In particular, land preparation, planting, and guarding take on greater importance. Also, the harvest labor requirement during October and November is of comparable magnitude to the weeding labor requirement in July and August.

Significant amounts of land preparation are required for sorghum. Possibly as a result of the land preparation requirement, planting did not begin until late June, which was after the early rains. Additional plantings in late July were required to replace plants killed off in the thirty-day drought at the beginning of the rainy season.

FIGURE 12 : Labor Requirements by Activity for Average Yield Sorghum Technology

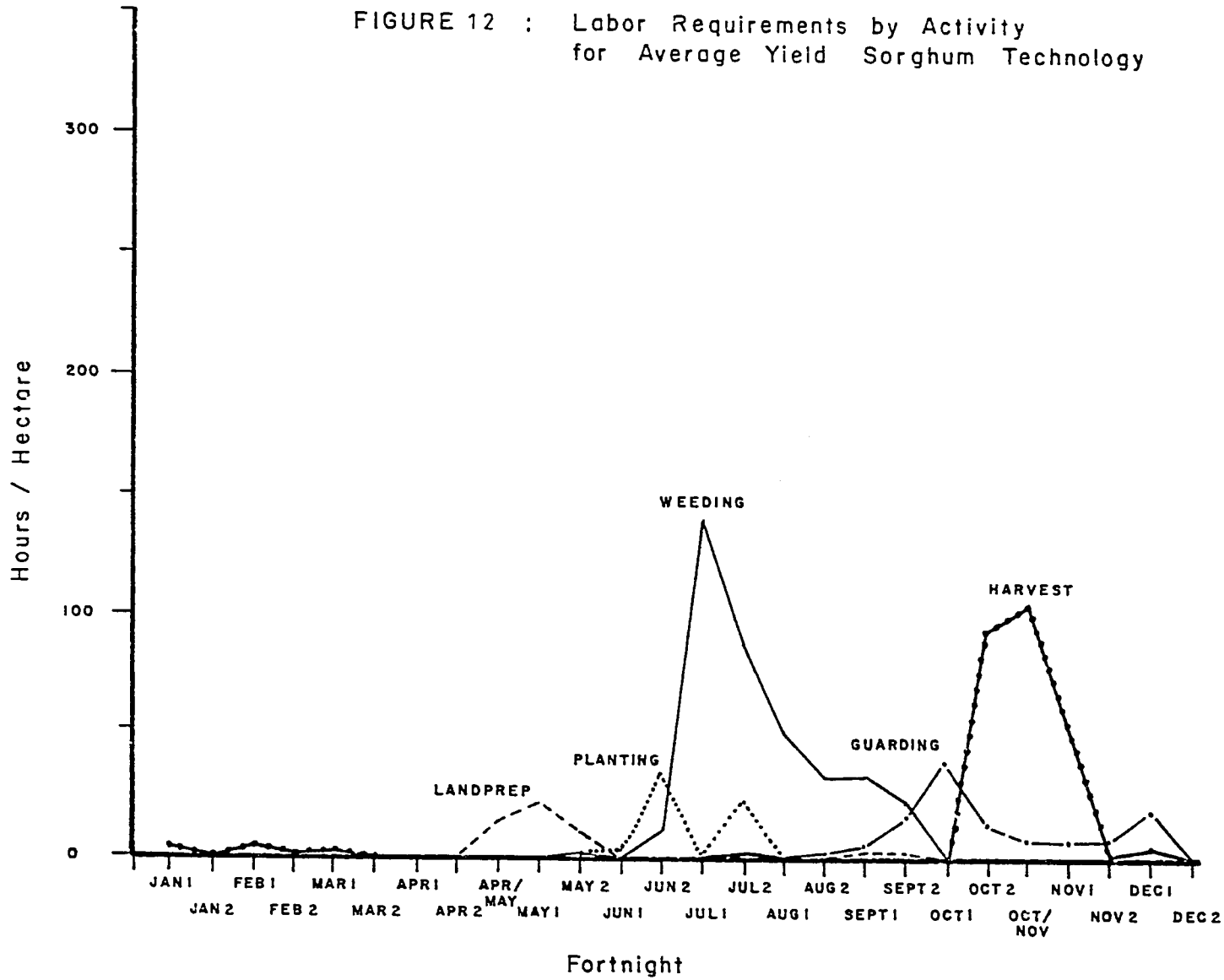
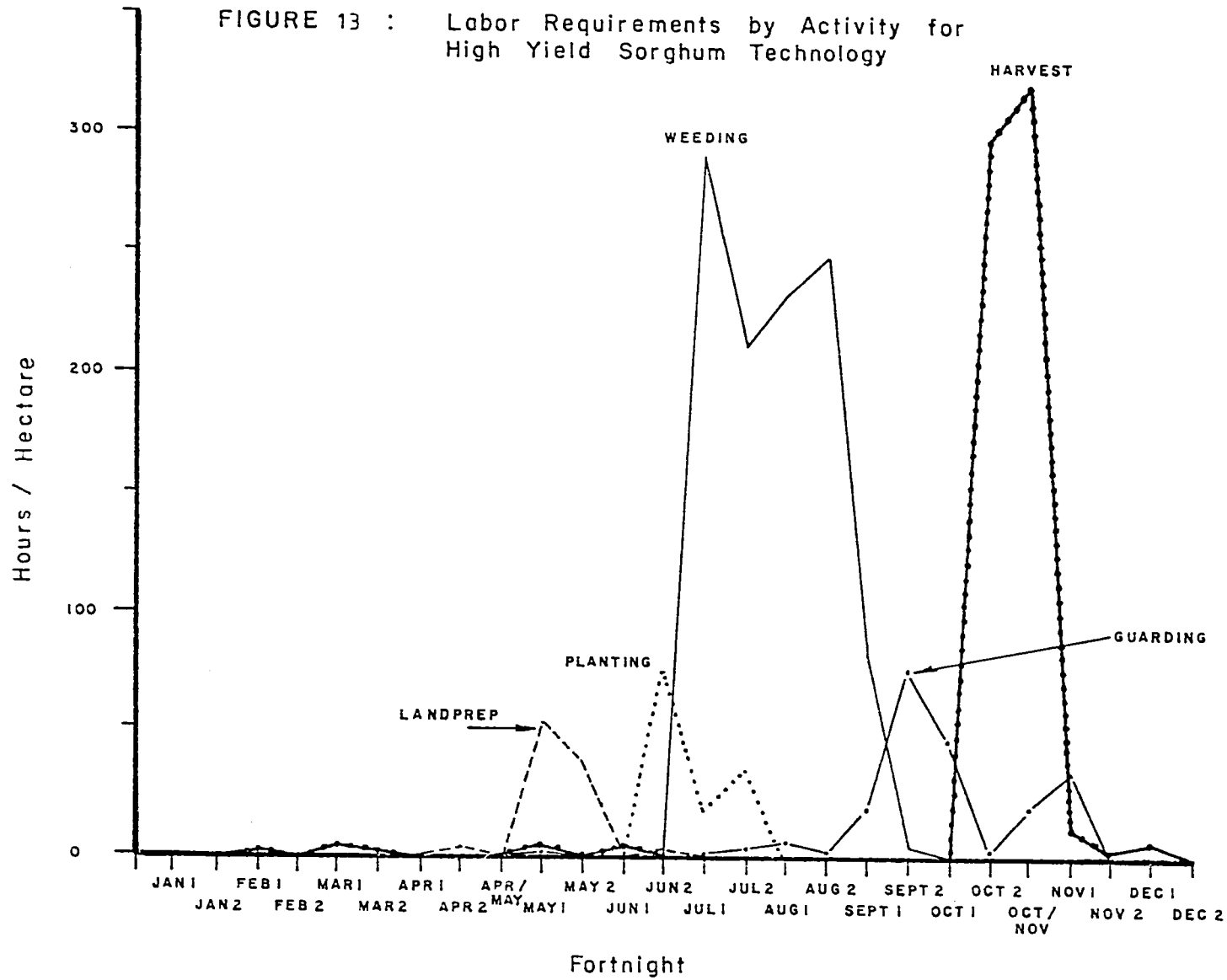


FIGURE 13 : Labor Requirements by Activity for High Yield Sorghum Technology



Unlike the Haussa millet technology, the peak requirement for labor allocated to weeding sorghum occurred in early July rather than August. A further difference is that the sorghum harvest began in earnest in late October, in contrast to the millet harvest, which commenced a month earlier. The later sorghum harvest meant that more labor had to be allocated to guarding the fields to prevent incursions by animals. The threat of trespassing animals was particularly acute at this time, since many animals were in transit through the area. Also, the heavy rains had stopped, and less pasture was available, making the ripening grain more attractive to transhumant herds. Finally, much of the pre-harvest labor in the grain fields had ceased, since the plants were already well established and the rains no longer made it necessary to continue intensive weeding. This meant that fewer people were regularly present in the grain fields, so there was a greater risk that animals would encroach upon unattended fields. As indicated by the timing of livestock labor requirements, the need to guard fields during this period may be an important constraint to agricultural production among mixed farmers.

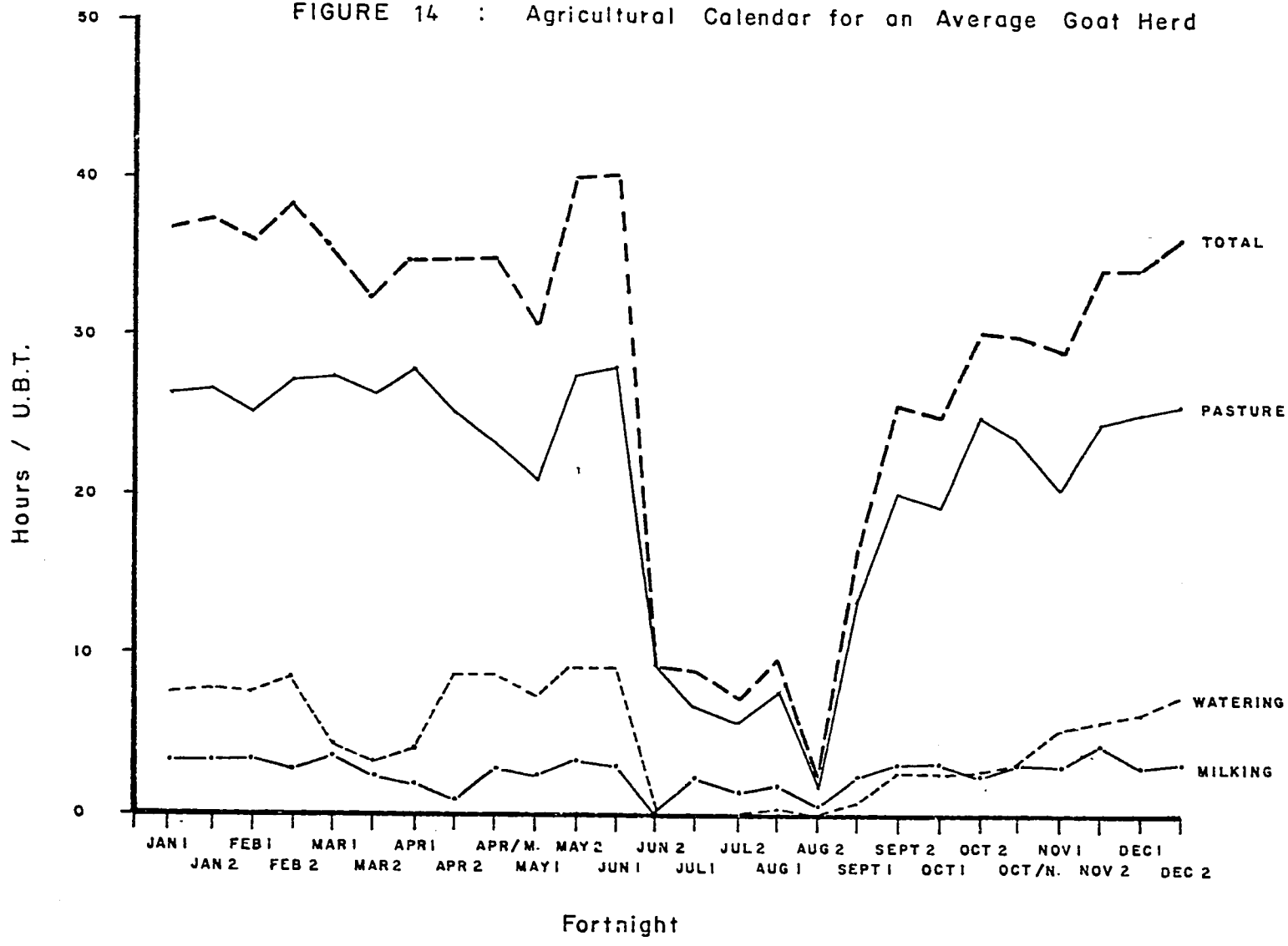
Goats.-- As indicated in the previous section, the livestock production options under consideration are limited to goats and cattle combined with goats, since these two types of herds were the most common among sample households. Furthermore, as indicated above in the subsection of livestock output, cattle were never raised independently of goats, since grain and livestock-producing households preferred to build up a subsistence herd of at least twenty goats before diversifying into cattle production. Before discussing the mixed herd option, the present subsection looks at the labor requirements of the basic goat herd, which contains twenty to twenty-five goats. As in the above discussion of livestock output, labor requirements for the goat herd and the mixed herd are given in terms of a standard unit (U.B.T.) which is equivalent to 5 goats or 1.2 head of cattle.

The breakdown of average labor requirements per animal unit for a sample of four Bush Tuareg goat herds is indicated in Figure 14. The most outstanding characteristic of the labor flows is the sharp drop in labor requirements from mid-June through August. This was the period during the rainy season when water and pasture were plentiful.

This was also the period when crops were in the ground and were developing. However, most crop producers were in their fields either planting or weeding at this time, so there was relatively little danger of animals wandering into the grain fields unobserved. Thus, during the height of the rainy season, the animals could be left to wander on their own in search of relatively abundant pasture and water, and more household labor could be devoted to grain production. For this reason, goat production labor requirements dropped to their annual low in late August when the combined requirements for weeding in both millet and sorghum fields were at an annual peak.

By September, the weeding of the grain crop was completed, and activities in the sorghum fields dropped off until the harvests began in October. As indicated above, the grain fields were vacant at this time (with the exception of those guarding the fields), and as the grain ripened, it became more attractive to the herds. As a result, the herds had to be placed under more regular surveillance to prevent them from entering the fields and damaging the grain crop. Thus, labor requirements rose sharply between August and September and increased more gradually throughout the harvest period as more labor was devoted to keeping the herds away from the ripening grain. At the same time, the amount of labor required for watering was increasing as surface water supplies dried up and herders had to begin watering their animals from the wells. The time required for milking also increased during this period since more animals in the herd were coming into milk. Thus, around the time of the grain harvest, sorghum and goat-producing households were faced simultaneously with rising demands for harvest labor and rising demands for labor allocated to all three major goat production activities. In contrast to the sharp dip during the rainy season, labor requirements were fairly stable throughout the cold season and hot dry season.

FIGURE 14 : Agricultural Calendar for an Average Goat Herd

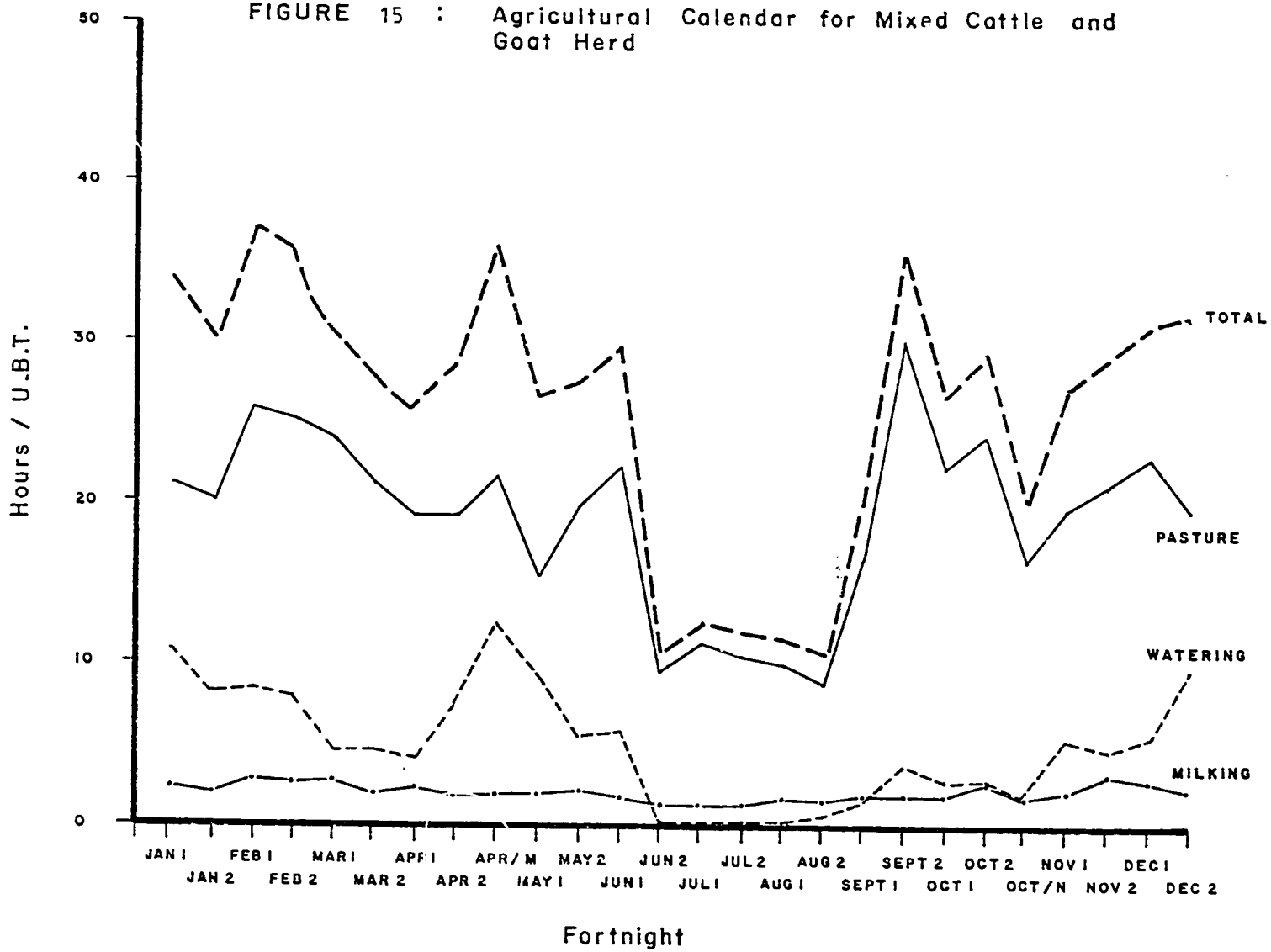


Mixed Herd of Cattle and Goats.-- Figure 15 illustrates the amount of labor required per animal unit and per fortnight to maintain a combined herd of twenty to twenty-five goats and three to five head of cattle. The overall pattern is very similar to that of the basic goat herd. In comparing the labor requirements per animal unit of the two types of herds, it does not appear that it is possible to realize any substantial economies of scale by expanding the basic goat herd to include cattle. Average labor requirements for both types of herds were similar in all but the June to August slack period.

The labor calendar for the mixed herd is marked by the same drop in labor requirements as that of the goat herd during the June to August period. However, average labor requirements per animal unit never dropped as low as those for the goat herd during this slack period. This probably was due to the fact that unattended cattle may do more damage to a grain field in a short period than goats. Therefore, cattle had to be watched more carefully than goats, even during the rainy season when water and pasture were more plentiful. Thus, the rainy season labor requirements for the mixed herd did not appear to be as flexible as those fo the goat herd.

This relative inflexibility of labor requirements applied equally well to the month of September, the time at the beginning of the grain harvest when labor requirements for the mixed herd rose to one of three annual peaks. During this time, the cattle had to be watched closely, since they in particular were attracted to the ripening heads of grain at a time when the grass cover which they relied on for feed was beginning to be depleted. The goats could still browse from trees and shrubs at this time, but the cattle did not have this option and were thus more attracted to the ripening grain. The following section examines the extent to which these differences in labor requirements interfere with the expansion of cattle production.

FIGURE 15 : Agricultural Calendar for Mixed Cattle and Goat Herd



Analysis of Bush Tuareg Agricultural Production

In this section, the information presented thus far is incorporated into a linear programming model of a Bush Tuareg mixed farm whose production possibilities are millet, sorghum, goats and cattle. The model is exploited to simulate the effects of three policy options intended to promote specialization in cattle production: (1) government distribution programs which grant or loan animals to livestock producers; (2) grain market interventions which would alter the price and quantity supplied of grain to the local market; and (3) the introduction of new technologies which would increase the milk yields of cows and goats. A critique of the results obtained and alternative policy recommendations follow in the final section of the paper. Briefly, the factors which appear to restrict Bush Tuareg cattle production and limit the efficacy of the above policies are: (1) seasonal labor bottlenecks at the beginning and end of the growing season; (2) the desire on the part of Bush Tuareg mixed farmers to be self-sufficient in grain; and (3) the importance of the goat as a relatively risk-free source of milk, meat, and cash income.

The Model.-- The basic model is a conventional farm management model which allows for selection among millet, sorghum, goat and cattle production activities subject to labor, land and subsistence constraints. The primal problem could be described as follows: with a given unit of value of each of the outputs (c_i) and a given upper limit for the availability of the labor input in each fortnight (b_j) and of the total land input to sorghum enterprises (l_s) what is the size of each activity (X_i), as measured in units of land and livestock, which would maximize the net value of the total output? The model can be expressed algebraically as:

$$Y = \text{MAX} \sum_{i=1}^{6} c_i X_i$$

subject to:

$$\sum_{i=1}^{6} a_{ij} X_i \leqq b_j \qquad (j = 1,\ldots,26)$$

$$\sum_{i=2}^{4} X_i \leqq l_s$$

where: Y = maximum value of output, net of seed, salt, and other purchased inputs

X_1 = millet activity (measured in hectares)

X_2 = low-yielding sorghum activity (in hectares)

X_3 = medium-yielding sorghum activity (in hectares)

X_4 = high-yielding sorghum activity (in hectares)

X_5 = goat activity (in U.B.T.)

X_6 = mixed cattle and goat activity (in U.B.T.)

i,j = subscripts indicating activity and time (fortnight), respectively

c_i = net value of output from one unit of the ith activity

a_{ij} = hours of labor required per unit of the ith activity in the jth fortnight in order to attain the yields implicit in the c_i.

b_j = total hours of labor available for agricultural activities in the jth fortnight

l_s = total hectares of land suitable for sorghum production (lowlands) which the household may expect to obtain.

The model offers as options six activities (enterprises), four of which are related to grain production and two to livestock. The four grain enterprises are measured in terms of the land input in hectares. Three of the grain enterprises involve sorghum production with three different per-hectare yields. The fourth is a millet enterprise based on the Haussa millet technology, as described in the previous section. It is assumed that millet and sorghum enterprises are distinct in that millet cultivation is confined to upland, predominantly sandy soils, and sorghum cultivation is likewise restricted to lowland alluvial soils. This was true for all households in the Bush Tuareg subsample.

The livestock enterprises consist either of goats alone or goats combined with cattle. Each of the livestock enterprises is measured in terms of U.B.T. equivalents (1 U.B.T. = 5 goats = 1.2 head of cattle). Cattle production is not an independent enterprise in the model, since, as previously indicated, all sample households which produced cattle also produced goats, and the labor inputs to the production of one animal type were inseparable from inputs to the production of the other. Therefore, combined goat and cattle production is considered to be one enterprise.

For the purposes of the combined livestock enterprise, it is assumed that there are equal numbers of U.B.T. equivalents of each animal type in the herd. Thus, each unit of the model goat/cattle enterprise contains the equivalent of 2.5 head of goats and 0.6 head of cattle. Each unit of the goat enterprise contains five head of goats. This conforms with the herd compositions assumed above in the calculation of the returns to and the average labor requirements for the respective enterprises.

In incorporating several sorghum technologies and two livestock enterprises, the model does allow for some flexibility in input (labor/land) ratios and herd composition. One potential problem with this formulation, however, is that it assumes that goats will always be combined with cattle in a proportion of at least four head of goats to one head of cattle (2.5 to 0.6). It is doubtful that this poses any great difficulty, since sample members actually did combine goats with cattle in at least that proportion. Furthermore, in the following analysis, whenever the combined livestock enterprise entered the optimal solution, additional units of the goat enterprise usually were selected along with the optimal number of units of the combined goat/cattle enterprise, indicating that the optimal enterprise combination usually involved combining goats with cattle in a ratio greater than 4-to-1. It should be borne in mind, however, that the model does not allow for a combination of goats and cattle in less than a 4-to-1 ratio.

Fixed labor requirements per hectare and per animal unit for each enterprise in each fortnight are derived from the material presented in the previous section. Labor requirements are specified for each enterprise in each fortnight in order to identify as precisely as possible the seasonal labor bottlenecks which constrain agricultural output. Since labor requirements are based on the average observed values within each group of households, the present model is limited to an approximation of the "average" Bush Tuareg household. The behavior of households which deviate in various respects from this overall "average" is simulated by adjusting the labor constraints to reflect the characteristics of larger households, as described below.

Value coefficients for the grain enterprises are the actual average net returns per hectare for the relevant group of households, as described in the previous section. These coefficients and the physical yields and prices on which they are based are listed in Table 7. Physical yields are net

of seed requirements for the following year.

TABLE 7

GRAIN PRODUCTION STATISTICS AND VALUE COEFFICIENTS
FOR MODEL GRAIN TECHNOLOGIES

	Millet	Sorghum		
Statistic:		Low-Yield	Medium-Yield	High-Yield
Hours/Ha	305.	530.	1,070.	2,157.
Kg /Ha	46.	300.	850.	1,160.
Kg /Hour	.15	.57	.79	.54
Value:				
Price (CFA/Kg)	68.	61.	61.	61.
CFA/Ha	3,128.	18,300.	51,850.	70,760.
CFA/Hour	10.20	34.77	48.19	32.94

The prices are the means of the weekly price observations recorded during the commodity price surveys conducted by the research team. The mean of the weekly observations, rather than an expected value based on grain sales patterns, was selected as the most representative price at which to evaluate grain output, since on the average, less than one-fourth of total grain production was marketed by Bush Tuareg households during the survey year. A sensitivity analysis of grain prices in the model is included in the following discussion.

The value coefficients for the two livestock enterprises are the measures of livestock output which were derived in the subsection covering that topic. Thus, the coefficients express the value of milk production, the appreciation in value of animals held in the herd (discounted for risk), and the value of surviving animals born into the herd. These coefficients are designed to estimate the return to one year's labor input which can be expected from one animal unit (one U.B.T.).

The returns to labor and livestock implicit in these coefficients are summarized in Table 8. The following analysis includes a sensitivity analysis of these coefficients, based on assumed increases in milk yields beyond the levels observed during the survey year. Since the value of milk

output accounted for more than half of the total estimated returns to livestock enterprises, the sensitivity analysis concentrates on that portion of the value of livestock production.

TABLE 8

ANNUAL RETURNS TO LABOR AND LIVESTOCK FROM MODEL LIVESTOCK ACTIVITIES

Statistic	Activity	
	Goats	Goats and Cattle
Hours/U.B.T.	734.	682.
CFA/U.B.T.	12,324.	16,405.
CFA/Hour	16.79	24.05

Labor constraints are formulated under the assumption that household members would prefer not to spend less time on commerce and domestic activities than that amount of time actually allocated to those activities during the survey year. Furthermore, it is assumed that each household member requires a minimum of three hours of rest during the twelve daylight hours of each day, including the amount of time spent at meals. Thus, the minimum rest requirement for each individual present in the household and the amount of time actually spent on commerce and domestic activities in each fortnight are deducted from the total amount of labor available,to arrive at an estimate of the maximum amount of labor available for agricultural enterprises in each fortnight for each household. These figures are then averaged over a given set of households to derive the labor constraints.

Two sets of households and the resulting two sets of labor constraints are considered in the following analysis. The first set consists of Bush Tuareg goat-producing households which were of average size relative to the entire set of households in the Bush Tuareg subsample. These will be referred to subsequently as the average Bush Tuareg households. Since cattle production was confined to households of above average size, the second set of households for which labor constraints are formulated consists of the larger Bush Tuareg households which produced both large and small ruminants. In the following discussion, these households will be referred to as the large Bush Tuareg households.

A land constraint is included to ensure that optimal solutions do not involve unrealistic land use plans. The land constraint affects only sorghum enterprises, since land suitable for millet production did not appear to be a scarce factor in the survey area. Thus, the constraint applies to those lowland, alluvial, primarily clay soils which were planted predominantly to sorghum.

The land constraint to sorghum enterprises was set at 5.00 hectares. This is the quantity of land suitable for sorghum production which Bush Tuareg households could reasonably expect to obtain. The constraint was never binding in any of the situations considered, suggesting that the availability of labor rather than the availability of land is what limits agricultural production on mixed farms in the southern pastoral zone.

In qualitative interviews, Bush Tuareg households indicated that given the choice between grain and livestock enterprises, they would prefer to assure subsistence needs in grain before engaging in livestock enterprises. To reflect this, a subsistence constraint was incorporated in the model, and solutions to the primal problem were examined with and without this constraint. To formulate the constraint, the minimum grain requirement per working household member was assumed to be the mean observed annual consumption of grain by households in the Bush Tuareg subsample. Thus, the subsistence constraint implies that the physical output of grain from the four grain activities must be greater than or equal to the observed consumption of grain for a set of households of a given size.

With the subsistence constraint introduced into the model, a parametric analysis of labor availability was conducted for households of various initial sizes. The results indicated that household size and labor availability are important determinants of enterprise combination. Specifically, the results suggested that, given the preferences and value-maximizing behavior outlined above, the ability to engage in cattle production while ensuring subsistence food needs is restricted to households of above average size. This would explain why only 30 percent of the sample households, all of which were of above average size, were engaged in the production of large ruminants at some point during the survey year.

Furthermore, it appeared that subsistence constraints were binding only for those households of average or below average size. The minimum grain production requirement imposed by the subsistence constraint did not

alter the optimal solution to the value maximization problem for the relatively large households. However, subsistence constraints were binding for smaller households and did effectively eliminate the possibility of cattle production by such households. Unless otherwise indicated, the subsistence constraint is not incorporated in the model for the purpose of the following analyses. However, separate consideration is given to the extent to which the solutions thus derived will fulfill grain consumption requirements.

The following analysis applies directly to a cross-section of Bush Tuareg households in a year in which, in addition to the other parameters in the model, the amount and distribution of rainfall was as observed during the survey year. This latter consideration is particularly important, since varying amounts and spatial and temporal patterns of rainfall would alter the labor requirements and possibly the relative profitability of agricultural enterprises. Thus, the results of the analysis, with the parameters as given, are useful for cross-sectional comparisons, but given the extensive variability of rainfall patterns in the southern pastoral zone, these results could not be used reliably to predict or explain behavior over time or between regions.

Simulated Effect of Increasing Herd Size. -- To simulate the effect of development programs whose aim is to distribute additional animals to livestock producers, a parametric analysis of herd size is conducted by setting the levels of one or both of the livestock enterprises to zero and then forcing increases in herd size by one animal unit at a time. The effect of the increases in herd size on the optimal levels of the other enterprises and on the total value of output is then examined. The analysis discloses that producers are currently maintaining herds which are of optimal or near-optimal size and that grants of additional animals, without complementary interventions to relieve currently binding constraints, would actually force a reduction in the total value of output.

The underlying rationale for animal distribution programs is that producers are not currently managing more animals simply because they cannot afford to acquire them. The logical extension of this is that the provision of credit or outright grants of animals would enable producers to expand their herds to their optimal size. However, since the following analysis discloses that producers are currently maintaining herds of optimal

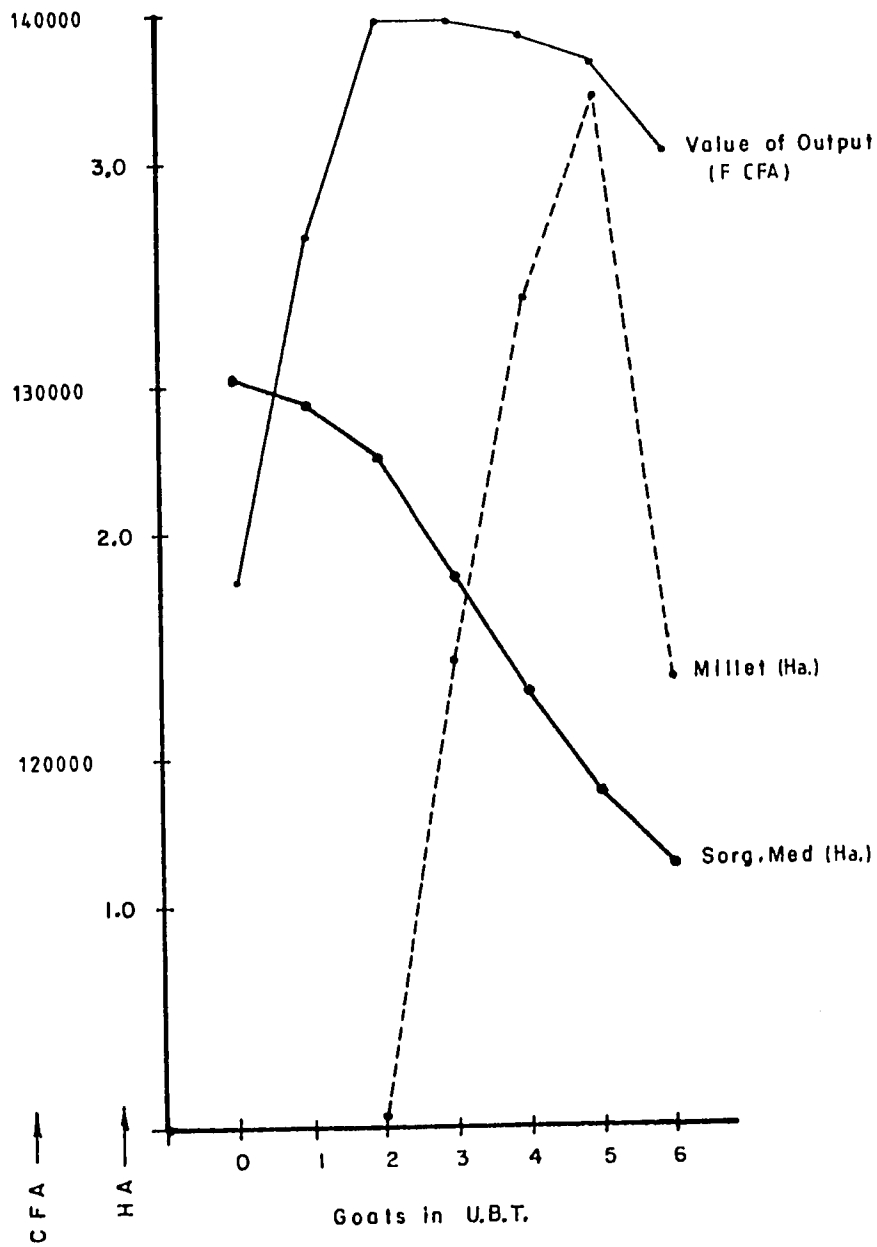
size, it then becomes relevant to ask what constraints limit the expansion of those herds and what complementary policy initiatives would relax such constraints. These are the subjects covered in the remainder of this paper.

The first portion of this section is concerned with the ability of the average Bush Tuareg household to expand goat production beyond current levels. The households in question currently maintain herds of approximately twenty goats, but no cattle. Since Tuareg households indicated that they were reluctant to engage in cattle production unless they could simultaneously maintain a subsistence herd of a least twenty goats, the following examines the effect of increasing the average household's goat herd beyond twenty head, or 4 U.B.T. Since the average Bush Tuareg household did not engage in cattle production, the combined cattle and goat production activity is excluded from the model when such households are the subject of the analysis. The specific issue investigated below is whether households of average size are operating their goat enterprises at optimal levels and, if so, what restricts the goat enterprise to a level at which such households are reluctant to take on the risk of incorporating cattle in their herds.

The results of the parametric analysis of goat herd size for average Bush Tuareg households are summarized in Figure 16. Given the model as stated above, maximum value of output for these households is attained at a goat herd size equivalent to 2 U.B.T., or 10 goats. Up to this point, the net value of output rises rapidly as goats are forced into the solution. Between this point and the point that coincides with current production levels (4 U.B.T., or 20 goats), the value of output declines gradually as goats are added. Beyond 4 U.B.T., the value of the objective function declines more rapidly. When a herd of 35 goats, or 7 U.B.T., is forced in, the solution becomes infeasible, given the labor constraints applicable to this set of households during the survey year. The solution given by the model with the goat herd size set at 20 head (4 U.B.T.) is quite close to the average enterprise size and combination observed among the relevant set of households.

As goats are added initially, the level of sorghum production in the optimal plan decreases, and millet production is substituted for some of the sorghum. Combining millet and sorghum production can be seen as a means of minimizing risk since the success of one or the other crop could not be known in advance due to uncertainty concerning rainfall. The millet

FIGURE 16 : Substitution Relationship Between Grain and Livestock Production with Varying Goat Herd Size: Average Bush Tuareg Household



crop is relatively more successful in years of higher rainfall, and the sorghum fields, being in low-lying areas which receive water from the surrounding hills, provide some grain even in years of abnormally low rainfall. Thus, the combination of grain enterprises ensures some millet output in years in which rainfall is abnormally high and the sorghum crop is drowned out, or a steady supply of grain from lowland sorghum fields in years such as the survey year, when rainfall is below average. The desire to produce both millet and sorghum in order to minimize the risk of total crop failure due to uncertain rainfall assists in explaining why Bush Tuareg households of average size were found to engage in goat enterprises at a scale beyond that which would appear to be optimal. Rather than maximizing the value of output by producing fewer goats, more sorghum, and no millet, producers may prefer to sacrifice some sorghum production in years of low rainfall in order to produce both millet and sorghum and more goats.

At a goat herd size of up to ten head and the optimal levels of millet and sorghum production associated with that herd size, output is constrained by labor availability in early July. However, when additional units of goats are forced into the solution, the most critical period of labor scarcity is late October. As explained above, the labor constraint in this period is due to the need to prevent the animals from consuming the ripened grain which is still in the fields and the need to evacuate the newly ripened grain to secure storage facilities.

The above analysis illuminates several important points. The first and probably most important point is that for the average Bush Tuareg household, there exists an optimal (or near-optimal) herd size of between 2 and 4 U.B.T. of goats (ten to twenty head), and that barring changes in technology, relative prices, or labor availability, the total value of output is drastically reduced when attempts are made to increase herd size beyond this optimal range. The second is that the desire to avoid risk by combining millet and sorghum production may force the producer to select a slightly sub-optimal enterprise combination. The third point is that within the range of enterprise combinations actually selected by this set of households during the survey year, the model indicates that the most critical period of labor scarcity is during the harvest period in late October. These results suggest that in the situation witnessed by the research team,

additional grants of animals, in the absence of complementary policy initiatives, would not enable the average-size household to expand livestock production without seriously affecting grain output and the total value of production from agricultural enterprises.

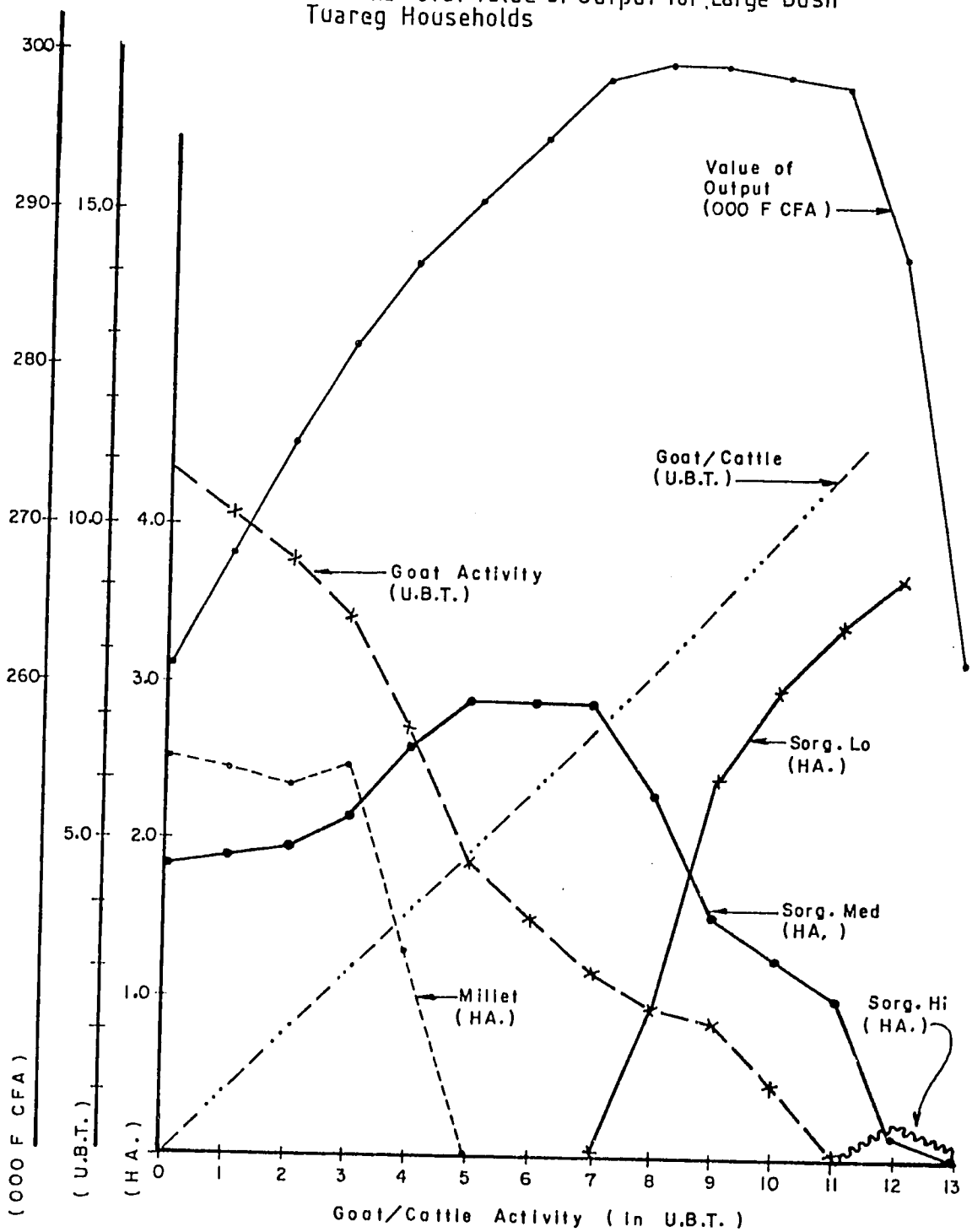
The second portion of this section is concerned with that set of Tuareg households which are large enough to keep both large and small ruminants while producing enough grain to satisfy the household's consumption needs. Cattle production by Tuareg mixed farmers was restricted to households of this size. Since it is found that these larger households also are operating at optimal levels for each enterprise, the analysis of this subsection also attempts to identify the factors which limit the effectiveness of animal distribution programs by restricting the expansion of cattle production.

The analysis centers around a set of parametric programming results which use the labor constraints applicable to large Bush Tuareg households. To obtain these results, the combined cattle and goat production activity was forced into the solution in increments of one animal unit (U.B.T.) up to the point where the introduction of additional goat/cattle units forced a sharp decline in the total value of output. The results of this exercise are illustrated in Figure 17. Each unit of the goat/cattle activity is assumed to contain equal proportions of U.B.T. equivalents of goats and cattle, or 2.5 goats combined with 0.6 head of cattle. Thus, with each increase of one unit of the goat/cattle activity, an additional 0.6 head of cattle are forced into the solution.

The analysis suggests that the value of output is maximized at a level of the goat/cattle activity which is close to 8 U.B.T., or five head of cattle. Furthermore, as other activities are allowed to adjust to optimal levels, the value of output is relatively insensitive to variations in the level of the goat/cattle activity between 7 and 11 U.B.T., which corresponds to four to seven head of cattle. This range and the optimal plans within it coincide with the range of enterprise sizes and combinations actually managed by Tuareg households of comparable size. The value of output declines abruptly when the goat/cattle activity is forced to levels outside of this range.

Based on Figure 17, the effects of the introduction of cattle into the herds of large Bush Tuareg households can be separated into four stages. The first stage is marked by a cattle herd of less than two head and a com-

FIGURE 17: Effect of Expanding Goat/Cattle Herus on Land Use and Total Value of Output for Large Bush Tuareg Households



plementary optimal plan consisting of millet, goats, and medium-yield sorghum. The second stage is associated with a cattle herd of between two and four head, or 3 to 7 U.B.T. of the goat/cattle activity. Within this range, as the cattle herd is increased, the millet activity is forced out of the solution, and the optimal size of the goat herd diminishes.

The third stage is associated with a cattle herd of between four and seven head (7 to 10 U.B.T.). In this range, as indicated above, the maximum value of output is attained, and the maximand is relatively insensitive to changes in herd composition. As the size of the cattle herd is increased within this range, the optimal size of the goat herd remains relatively stable, but labor constraints during the early harvest period force the substitution of the less labor-intensive sorghum technology for the medium-yield technology. This switch to the less labor-intensive grain technology would assist in explaining why some surveys indicate that cattle-producing households achieve lower per-hectare grain yields than similar households not producing cattle. Finally, in the fourth stage, as the size of the cattle herd increases beyond seven head, the total value of output and the size of all grain enterprises declines abruptly.

As cattle are introduced in the first two stages of the above sequence, agricultural output is limited by labor scarcity in late October. However, in the third stage, as the size of the cattle herd is increased beyond five head, the scarcity of labor in late September becomes a more important restriction on the expansion of agricultural output than the late October labor constraint. As explained in the previous section, this is because the larger cattle herds require more care at the beginning of the grain harvest, when they must be kept away from the ripened grain which is still standing in the fields. This suggests that efforts to expand cattle production among large Bush Tuareg households should be accompanied by some means of alleviating the September labor constraint.

This section has concentrated on using the model to derive the optimal enterprise mix associated with each stage of expansion of the livestock herd. The analysis has focused on Bush Tuareg households of either average or above average size. The results suggest that the average Bush Tuareg household is limited to a livestock herd consisting of no more than twenty head of goats. The results also suggest that even the largest Bush Tuareg households are limited to a herd of thirty goats and, at most, seven head of cattle. As

herds are expanded beyond these optimal levels, labor constraints force a sharp reduction in the total value of output and in total grain production. This indicates that animal distribution programs alone are unlikely to be effective in increasing cattle production on Bush Tuareg mixed farms.

The simulation shows that if the opportunity to produce livestock were eliminated, the value-maximizing model household would select an average-yield (850 kg /ha) sorghum enterprise. As goats and then cattle are forced into the solution, the model household shifts to less productive grain enterprises such as millet (46 kg /ha) and the less labor-intensive sorghum enterprise (300 kg /ha). The net value of total output initially rises, and total grain production initially declines. As herds are expanded beyond the levels stated above, however, and the size of grain enterprises is allowed to adjust to optimal levels, both the value of total output and total grain production decrease rapidly.

Since similar sample households are now producing at or near the optimal levels of the livestock enterprises indicated by the parametric analysis, it then becomes relevant to identify the binding labor constraints and suggest means of alleviating those constraints. In the case of the average Bush Tuareg household, labor availability becomes a binding constraint to the expansion of agricultural enterprises in late October at the time of the grain harvest. This constraint also effectively prevents the household of average size from engaging in cattle production, given the following set of preferences: 1) the desire to produce enough grain to fulfill the household's subsistence needs; 2) the desire to diversify grain production to avoid the risk of crop failure in years of abnormal rainfall; and 3) the desire to acquire and maintain a herd of at least twenty goats before engaging in the more risky cattle enterprise.

Although the larger households in the sample were able to meet the above requirements and still engage in cattle production, labor constraints for the large model households still restricted optimal enterprise size and combination to no more than thirty goats and seven head of cattle. At near-optimal herd sizes, the analysis indicated that labor constraints for such households are binding in early July and late September. The former constraint occurs during the peak period of weeding activity in the sorghum fields. The latter comes during the pre-harvest period following the completion of weeding when animals must be kept away from the ripening grain.

Policy initiatives which may assist in alleviating the constraints identified above will be discussed later in the chapter. Prior to that, however, the following section uses the model to examine a different approach to the problem of increasing cattle production among Bush Tuareg mixed farmers.

Simulated Effect of Decreasing Grain Prices. -- This section uses the model to simulate the effects of marketing interventions on optimal enterprise size and combination. The interventions in question are those which would lower grain prices at the local market, thus raising the relative profitability of livestock production. To conduct the simulation, the grain prices used to calculate the value coefficients of millet and sorghum enterprises were lowered by as much as 50 percent of their original levels while holding all other parameters constant.

As in the previous section, the analysis is restricted to Bush Tuareg households of average or above average size. Once again, the primary reason for this choice is that when compared to other sample households, these households appear to have the greatest potential for entering into or increasing cattle production in the near future. More importantly, from among the three production systems surveyed, Bush Tuareg households are probably the most representative of the majority of crop and livestock-producing households in Niger's southern pastoral zone.

To conduct the sensitivity analysis of grain prices, prices were reduced in 5 F/kg increments from the average retail prices for grain used in the previous section (68 F/kg for millet and 61 F/kg for sorghum). Solutions to the value-maximization problem were obtained after each incremental change in the coefficients as a result of the changes in grain prices. The results of such an analysis as applied to the average Bush Tuareg model household are shown in Table 9.

The analysis indicates that solutions to the value-maximization problem are initially quite sensitive to changes in the coefficients. The optimal size of the goat herd increases from eight head (1.66 U.B.T.) to approximately twenty-five head (5.07 U.B.T.) after a decrease in grain prices of only 7 percent (5 F/kg). A decrease in grain prices of 15 F/kg, or approximately one-fourth of the original price, further increases the optimal size of the goat herd to thirty-three head (6.58 U.B.T.).

TABLE 9

EFFECT OF DECREASING GRAIN PRICES ON LAND USE, GOAT HERD SIZE, AND THE NET VALUE OF OUTPUT FOR THE AVERAGE BUSH TUAREG HOUSEHOLD

Change in Grain Prices (CFA F/kg)	Crops (in Ha)		Goats[a] (UBT)	Net Value of Output (CFA F)
	Millet	Sorghum (average yield)		
0		2.31	1.66	140,034.
- 5	3.21	1.28	5.07	132,567.
- 10	3.21	1.28	5.07	126,397.
- 15	.58	1.00	6.58	121,510.
- 20	.58	1.00	6.58	117,142.
- 25	.58	1.00	6.58	112,774.
- 30	.58	1.00	6.58	108,406.

[a]The combined goat/cattle enterprise was eliminated from the model for the purposes of this analysis.

Presumably, such a decrease in grain prices would raise the optimal size of the goat herd to the point where the average household could reasonably consider the introduction of the cattle enterprise, knowing that they could rely on their larger goat herd to offset the risks entailed in the new enterprise. In other words, the decrease in grain prices would make it profitable to acquire a goat herd sufficiently large for the household to consider expanding into cattle production. Furthermore, if the drop in prices would induce the household to rely on the local market as a source of subsistence grain, then the subsistence constraint on grain production would no longer be relevant. The final result would be that the average household could engage in cattle production without fear of the risks involved in that enterprise nor of the risk of falling short of subsistence needs in grain as long as the market provided high-quality grain at the reduced prices indicated.

The results of a similar analysis as applied to the larger Bush Tuareg households are listed in Table 10. The results obtained are comparable to those discussed above for the average household. With a 7 percent decrease in grain prices, the optimal herd size and composition changes from thirty-two goats and four or five head of cattle to thirty-four goats and six head of cattle. A further drop in grain prices down to 85 percent of the original level would cause a shift in the herd composition towards cattle so that the optimal herd becomes one of twenty-eight goats and seven head of cattle. This solution remains fairly stable throughout the further reductions in grain prices indicated in Table 10. The stability of the solution in this range may be deceptive, however, since the model does not allow for complete specialization in livestock. Were such an alternative to be included in the model, it is conceivable that the optimal size of the cattle herd would continue to increase as grain prices are reduced by amounts greater than 10 CFA F/kg below original levels.

Despite the shift towards livestock production induced by the fall in grain prices, the above analyses suggest that at least for small changes, more land would be put into grain production as grain prices decline. This is a result of the shift to more land-extensive grain production technologies as the size of livestock enterprises increases. A similar shift was noted in the analysis described in the previous section.

TABLE 10

EFFECT OF DECREASING GRAIN PRICES ON LAND USE, HERD SIZE, AND THE NET VALUE OF OUTPUT FOR THE LARGE BUSH TUAREG HOUSEHOLD

Change in Grain Prices (CFA F/kg.)	Sorghum[a] (Ha.)			Livestock (UBT)		Net Value of Output (CFA F)
	Low Yield	Average Yield	High Yield	Goat Enterprise	Combined Goat/Cattle	
0		2.82		2.67	7.33	299,696.
- 5	2.61	1.45		2.15	9.14	289,106.
- 10	3.45	1.00			11.16	279,090.
- 15	3.45	1.00			11.16	269,679.
- 20	3.45	1.00			11.16	260,268.
- 25	3.67	.52	.17		11.50	251,226.
- 30	3.69		.25		12.18	243,010.

[a]Millet did not enter into the optimal solution.

Simulated Effect of Increasing Milk Output. -- The following analysis simulates the effect of technological innovations which would increase the milk yield obtained from the two livestock enterprises while all other parameters (including grain prices) in the model are held constant at their original levels. Since the estimates of the value of output from the two livestock enterprises derived above indicate that more than half of the net value of output is obtained from milk production, technological innovations aimed at increasing milk yields should have a greater impact on increasing the relative profitability of livestock enterprises than would marketing interventions aimed at increasing animal prices. For this reason, the present analysis concentrates on the effect of increases in milk yields.

The average milk yields for goat and combined cattle and goat enterprises were 124 liters per U.B.T. for the former and 189 liters per U.B.T. for the latter. In conducting the parametric analysis, it was assumed that since observed milk yields from the combined livestock enterprise were 50 percent greater than yields from the goat herd alone, then the appropriate rate of increase of milk yields for the combined enterprise would also be 50 percent greater than the rate of increase for the goat herd. This is predicated on the assumption that yield-increasing technological innovations would have a greater impact on cattle than on goats.

Accordingly, the parametric analysis was conducted by forcing incremental increases in the value coefficients commensurate with increases in the goat milk yield of ten liters per U.B.T. per year and increases in the combined cattle and goat milk yield of fifteen liters per U.B.T. per year. In either case, the incremental increase corresponds to a rise in milk yields of 8 percent above original levels. Yields were made to increase in this fashion up to the point where the physical yield of milk from each enterprise was 50 percent greater than the initial yield.

In value terms, each incremental increase in yields corresponded to an increase in the value coefficient (c_i) of the goat enterprise of 500 F/U.B.T. and that of the combined enterprise of 750 F/U.B.T.[1] Therefore,

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[1]Market surveys revealed that the prevailing price of milk during the survey year was 50 CFA F/liter.

the initial incremental increase in milk yields produced a 4 percent increase in the value coefficient for the goat enterprise and a 5 percent increase in the coefficient for the combined enterprise. At the maximum level of change associated with this analysis (an increase in yields corresponding to 50 percent of the initial yield), the value coefficients were increased to 24 percent and 27 percent over the initial levels for the goat and the combined cattle and goat enterprises, respectively.

The option of producing cattle was eliminated for the average Bush Tuareg model household, as it was for the previous analysis of grain prices. Therefore, for such households, the analysis was restricted to determining the change which would be required before the optimal size of the goat herd would increase to a level at which cattle could be introduced without undue risk. Once again, it was assumed that, as stated by the sample members themselves, cattle would not be introduced until the household had acquired a herd of at least twenty goats.

The results of such an analysis as applied to the average Bush Tuareg household are shown in Table 11. The results indicate that an increase in the milk yield of goats of twenty liters per U.B.T., or 16 percent, would raise the optimal size of the goat herd from eight to twenty-five head. Presumably, the increase would raise the relative profitability of livestock enterprises to the point where the household could comfortably introduce cattle. The solution remains stable as milk yields are increased further, and the only additional change in the optimal enterprise mix occurs when yields are increased to 1.5 times current levels.

When the same type of analysis was applied to the large Bush Tuareg model household with the goat/cattle enterprise in the objective function, the model generated the results given in Table 12. When compared with Table 11, the table shows that a 24 percent increase in milk yields would have the same effect as a 15 percent decrease in grain prices. Either change by itself would change the optimal size and composition of the herd from thirty-two goats and four to five head of cattle to twenty-eight goats and seven head of cattle. The same problem mentioned in the discussion of the previous analysis would be applicable to increases in milk yields beyond the level mentioned above, i.e., the model does not allow for

TABLE 11

EFFECT OF INCREASING MILK YIELDS ON LAND USE, GOAT HERD SIZE, AND THE NET VALUE OF OUTPUT FOR THE AVERAGE BUSH TUAREG HOUSEHOLD

Change in Milk Yield (l./UBT)	Crops (Ha)		Goats (UBT)	Net Value of Output (CFA F)
	Millet	Sorghum (average yield)		
0		2.31	1.66	140,034.
+ 10	2.39	1.70	3.60	141,588.
+ 20	3.21	1.28	5.07	143,802.
+ 30	3.21	1.28	5.07	146,336.
+ 40	3.21	1.28	5.07	148,869.
+ 50	3.21	1.28	5.07	151,402.
+ 60	.57	1.00	6.58	154,365.

TABLE 12

EFFECT OF INCREASING MILK YIELDS ON LAND USE, HERD SIZE, AND THE NET VALUE OF OUTPUT FOR THE LARGE BUSH TUAREG HOUSEHOLD

Change in Milk Yield (l./UBT)		Crops (Ha)		Livestock (UBT)		Net Value of Output (CFA F)
Goat Enterprise	Combined Goat/Cattle Enterprise	Sorghum (low yield)	Sorghum (average yield)	Goat Enterprise	Combined Goat/ Cattle	
0	0		2.82	2.67	7.33	299,696.
+ 10	+ 15	2.61	1.45	2.15	9.14	307,097
+ 20	+ 30	2.61	1.45	2.15	9.14	315,025.
+ 30	+ 45	3.45	1.00		11.16	323,024.
+ 40	+ 60	3.45	1.00		11.16	331,394.
+ 50	+ 75	3.45	1.00		11.16	339,765.
+ 60	+ 90	3.45	1.00		11.16	348,136.

a ratio of goats to cattle in the household herd of less than 4:1.

The initial increases in milk yields bring about the same effect on land use as did the initial decreases in grain prices. For the large Bush Tuareg household, the optimal area planted to grain increases along with the optimal size of the household herd as milk yields are increased by less than 24 percent of the original yields, or as grain prices are decreased by less than 15 percent of the initial prices. Similarly, for the average Bush Tuareg household, the optimal area planted to grain increases along with the optimal size of the goat herd as milk yields are increased by less than 50 percent of the original yields, or as grain prices are decreased by less than 25 percent of the initial prices. This suggests that either of the two policy initiatives could be combined with innovations aimed at alleviating binding labor constraints to avoid forcing a shift to less labor-intensive grain production technologies as livestock enterprises expand.

Basically, the effect of the two policy initiatives on labor constraints is to accentuate the importance of binding labor constraints just prior to and during the grain harvest. For instance, for the large Bush Tuareg household, the shadow price of labor in late September increases from 345 to 387 CFA F per hour as grain prices are cut in half and livestock enterprises are expanded and from 345 to 478 CFA F per hour as milk yields are increased by 50 percent. Late September is consistently the period when the shadow price of labor is highest and is increasing most rapidly as grain prices fall or as milk yields rise, thereby prompting an increase in the optimal size of livestock enterprises.

Similarly, for the average Bush Tuareg household not producing cattle, late October remains the period when the shadow price of labor is highest. As a rise in milk yields of up to 50 percent increases the optimal size of the goat herd, the shadow price of labor in late October increases from 399 to 445 CFA F per hour. As grain prices fall to half of their previous level and the optimal size of the goat herd increases, the shadow price of labor in that period is still the highest, although it decreases from 399 to 196 CFA F per hour. These two sets of results suggest that when combined with either of the policy initiatives examined in this section, complementary initiatives aimed at relieving labor constraints will have the greatest impact on increasing optimal herd size if they are designed to

ease constraints occurring just before or during the grain harvest (i.e., during September and October). Methods of relaxing the constraints occurring during this period will be examined in the remainder of this paper.

Summary of Major Results

This section contrasts national development objectives with the objectives of the individual mixed farmer living in the pastoral zone, as reflected in the analysis. While the national objective may be to increase the production of cattle for export, residents of the southern pastoral zone subsist on grain, not cattle, and are reluctant to reallocate resources away from grain production. The social costs associated with continued grain production in the pastoral zone are contrasted in the following discussion with the desirability of grain and goat, but not cattle, production for the individual farmer.

Social Costs Associated with Current Production Patterns in the Pastoral Zone.-- Proponents of the stratification strategy feel that specialization in cattle production by residents of the pastoral zone is in the national interest and that the present allocation of land and labor resources to grain production in that area is inefficient. If this is indeed the case, then there must be some way to reallocate land and labor to cattle production in such a way that the welfare of some individuals can be improved either without adversely affecting anyone else, or by being able fully to compensate damaged parties and still have a net benefit to others. The national planners who advocate specialization believe that the revenues, and in particular the foreign exchange earnings to be gained from the sale of cattle to coastal countries, would provide the additional benefits to be expected from a more efficient resource allocation. The problem, as illustrated below, is that the individual mixed farmer does not perceive the same benefits to be gained from specialization in cattle production as those envisioned by the national planners.

Aside from the alleged opportunity cost associated with inefficient resource allocation in the form of continued grain production in the pastoral zone, there is an additional social cost associated with current production patterns which does not enter into the calculations of the individual producer. The cost in question is the reduction in value of the land resource caused by overexploitation by both crop and livestock

producers. The history of land use in the southern pastoral zone illustrates the causes of the gradual deterioration of the resource base which has occurred during this century and which was accelerated by the period of drought which began in 1968. The first in this sequence of events is the subjugation of the Tuareg warlords by French colonial forces at the beginning of this century and the dissolution of the feudal system of land tenure which they enforced. The period following the pacification of the pastoral zone was one of abnormally high rainfall. The abundant rains, combined with the pacification of the Tuareg and the resultant availability of new land for cultivation, prompted a northward migration of Haussa grain producers during the two decades following the second World War.

Around the same time as the Haussa migration northwards, mechanized deep-bore water pumping stations were opened throughout the pastoral zone. The opening of the pumping stations attracted a larger number of Fulani herds than the area had supported previously. These herds also grew more rapidly as widespread cattle vaccination programs eliminated certain endemic diseases.

The influx of Haussa grain producers and Fulani cattle herders contributed to the devastating effects of the recent drought on the land resources of the pastoral zone. However, the pressure of increased population and the conflicting demands of the various production systems has not been relieved since the drought began. Rather than terminate grain production entirely and leave the area, Haussa grain producers and dispossessed Tuareg herders (Village Tuareg) have congregated in the market towns and have turned increasingly to commerce as the main source of household income. This tendency has been furthered in recent years by the growth in the importance of Kao and similar villages in the southern pastoral zone as the major livestock and commodity markets which service the pastoral zone have shifted north. This northward movement of the major livestock markets provided an alternative source of income for those village-dwellers who could no longer rely on their own grain production as a source of food. However, such households have continued to produce grain, often with the assistance of hired labor, since they have little to lose

by doing so, their subsistence being assured by their income from trade. They can hire laborers to plant large areas of land, but avoid further costs merely by abandoning the field if the crop does not come up well. The system of land tenure may encourage such practices, as will be explained below.

Prior to subjugation of the Tuareg by colonial forces, the pastoral zone was, as its name belies, a region specialized in livestock production. Its success in this role was dependent on a system for controlling access to rangeland which was enforced by the Tuareg warlords. Most importantly, prior to this century, the southern portion of the pastoral zone -- including the area covered by the survey -- was set aside as a dry season grazing reserve. Animals were evacuated from the area during the rainy season, when they could take advantage of northern pastures. This system of seasonal migration allowed the pastures of the southern pastoral zone to develop during the rainy season so that livestock producers could rely on them as a source of forage once the rains stopped and pastures in the north had been exhausted.

However, with the expansion of grain cultivation and the influx of Fulani herds from the south, this system of seasonal migration, which allowed the pastures of the southern pastoral zone to develop during the rainy season, was abandoned. Obviously, few would benefit from a reinstatement of the Tuareg feudal system of land management. But in order to prevent further deterioration of the land resource and allow the pastoral zone to develop its potential as a breeding zone for livestock, some system of land management which encourages the protection of dry season grazing reserves must be introduced.

The challenge, therefore, is to find a system of land management which is enforceable and which limits, but does not preclude, grain cultivation, an activity which residents of the southern pastoral zone seem hesitant to abandon. Banning grain cultivation outright is not the solution. The 1961 law which defines the pastoral zone and which prohibits grain cultivation within it has never been effectively enforced. Part of the reason why it has not been effective is simply because it is contrary to the self-interest of the individual producer, as explained in the following section.

The Individual Farmer's Reluctance to Abandon Grain Cultivation and Specialize in Cattle Production.-- Despite the apparent national interest in promoting specialization in cattle production within the pastoral zone, the individual mixed farmers who inhabit the southern portion of that zone continue to allocate labor and land resources to grain and goat production rather than cattle. There are several reasons underlying this choice of activities. In the first place, over half of the mixed farm household's food needs, in terms of energy intake, are derived from grain consumption, whereas the consumption of livestock products contributes no more than percent of energy requirements. The only alternative to household production as a source of grain is the market, but residents of the pastoral zone have had unfortunate experiences with this means of obtaining grain. In particular, the fluctuations in the price and supply of grain on the market during the recent drought accentuated the hazards of relying on the market to provide such an important component of the household diet. Furthermore, increases in the price of fuel have raised transportation costs, which are passed on to the consumer in the form of higher prices for grain shipped to the pastoral zone from the agricultural zone to the south. Also, much of the grain which is offered for sale in the markets of the pastoral zone is of lower quality than that produced locally and stored in local granaries.

The linear programming analysis indicated that for Bush Tuareg households, increases in herd size beyond current levels would force a decrease in grain output. If the objective of development policy is to promote livestock production while confining the area planted to grain and conserving the quality of the land resource, confidence in the grain market must be developed. Policy recommendations along these lines are discussed in the following section.

Another reason why individual mixed farmers are hesitant to specialize in cattle production is the comparative advantage of the goat as a less risky source of food and cash income. There are several reasons why sample households -- and Tuareg sample households in particular -- preferred goats over other animal types. Goats are more resistant to the severe climate and particularly to drought conditions. They can browse trees and exploit

sources of feed otherwise unacceptable to cattle, and their water requirements per standard animal unit are lower than the water requirements of cattle. They also offer several advantages for the herd manager in that they have less of a tendency to stray and require less attention than cattle. A young boy can handle a goat herd, but older males are more often required to manage cattle. The goat herd also is more manageable in that individual units within it are smaller and of lower value. Less initial investment is required than in the case of the cattle herd, and less risk is associated with the individual animal. Furthermore, goats can be sold to meet immediate cash needs, whereas the sale of cattle requires a larger disinvestment and more advance planning. For these reasons, it was found that mixed farmers were hesitant to diversify their livestock holdings by acquiring cattle until they had built up a herd of at least twenty goats.

Finally, the linear programming analysis indicated that Tuareg mixed farms desiring to expand their cattle herds faced labor constraints at the beginning and end of the growing season. In the simulation, as cattle herds increased in response to policy initiatives which raised the profitability of livestock enterprises relative to grain, the labor constraint just prior to the harvest in late September increased in importance. This is of particular significance, since rainfall during this period was less atypical during the survey year than in either of the other two periods (early July and late October) when labor availability restricted agricultural output.

The unusual rainfall patterns in early July and late October suggest that constraints which occurred at those times might not be as critical in years in which the rainfall distribution is closer to the average. In 1976, a thirty-day drought struck the survey area from late June to late July, in the midst of the growing season. The need to replant fields at the end of this period may have imposed a labor requirement which might not be present in years in which such a drought did not occur. Also, in 1976, rainfall in October was well above average, and as a result, the sorghum harvest was prolonged.

The unusually heavy rainfall at the end of the growing season may have distorted the labor requirements normally associated with harvesting.

However, there is no indication that activities were abnormally affected by rainfall in September 1976. The constraint which arose at that time came from the need to guard cattle to keep them away from the ripening grain while simultaneously guarding the grain fields to keep others' animals away from them. This suggests that the September labor constraint is not only the most important in terms of the increasing opportunity cost of labor as cattle herds expand, but also that it is the most likely to persist under different rainfall conditions. The need to guard the animals as well as the grain fields just prior to the harvest will always be a problem. The following section presents some attempts to resolve that problem as well as others raised by the results of the formal analysis.

Policy Recommendations

The previous section has illustrated the extent of the disparity between national and individual objectives. The present section discusses a set of policy recommendations which might reconcile the two viewpoints. These policy recommendations are aimed at increasing cattle production by mixed farmers in the pastoral zone while restricting the area planted to grain and preserving the quality of the land resource. The analysis thus far has indicated that policies aimed at increasing the relative profitability of cattle production will not of themselves be sufficient to divert land and labor resources away from grain and into cattle production. Such policies must be accompanied by complementary initiatives. Structural changes are required in addition to simple marginal changes in technologies and prices. One such initiative proposed below is the attribution of seasonal property rights to livestock producers, which could relieve the September labor constraint, preserve the quality of the land resource, and to some extent internalize the social costs associated with the overexploitation of land. Associated land tenure reforms which would discourage those who have alternative sources of income from continuing the expansion of grain production would be another complementary initiative.

The introduction of labor-augmenting changes in grain production technology would enable labor resources to be reallocated from grain to cattle production without decreasing grain output or increasing the area planted to grain. However, this approach does not respond to the problem of protecting the land resource. A more appropriate strategy, which would respond more directly to the concerns of the individual producer, would be the development of the market as an alternative to household grain production. Along the same lines, development projects aimed at goat production might enable the relatively impoverished producer to expand into cattle production more rapidly. Specifically, increases in the milk yields of goats might decrease the size of the subsistence herd required to assure a steady milk supply prior to diversification into cattle. These alternatives are explored in the following discussion.

Increasing the Relative Profitability of Cattle Production.-- The linear programming analysis has indicated that the production of grain is currently a rational choice of activities for the profit-maximizing producer. The actual choice of grain and livestock production activities by Tuareg mixed farmers is now close to optimal levels indicated by the model. One approach to altering this choice of activities and bringing it more in line with the national objectives outlined above would be to increase the relative profitability of cattle production.

Three policy options which would embody this approach were examined in the formal analysis. The first consisted of grants of animals to mixed farmers. Such programs have been underway for the past several years, but their outreach has been limited to Fulani herders currently specializing in cattle production. Using the techniques of parametric programming, the analysis indicated that if such programs were to include mixed farmers, they would have relatively little impact on cattle production unless accompanied by programs aimed at relieving the

labor and subsistence constraints embodied in the model. Without such complementary programs, increasing the size of herds held by Tuareg mixed farmers beyond current levels would force a shift to more land-extensive grain production technologies and a commensurate decline in the net value of agricultural output. Such a shift would hardly be desirable. Also, as the analysis indicated, the shift to more land-extensive technologies would involve allocating more land to grain production in order to fulfill the household's subsistence needs.

Two policy alternatives which might shift the economic advantage to livestock production were selected for analysis. The first was to lower the relative price of grain, and the second was to increase milk yields. The two initiatives suffered similar fates in the simulation. The expansion of the herds as a result of the increase in the relative profitability of livestock production was accompanied by an increase in the area planted to grain caused by a shift to less productive grain technologies. The shift to less productive grain technologies as the cattle herd expanded was made necessary by the increase in the importance of the September labor constraint. The following policy approaches are designed to address this problem.

The Extension of Seasonal Enforcement of Property Rights to Livestock Producers.-- Currently, the only legally-enforceable private interest in land recognized in the survey area is the right of the grain producer to cultivate his fields without interference from trespassing herds. If trespass by animals results in actual damage to the crop, no matter how slight, a cause of action arises, and the grain producer may bring his claim before a local tribunal headed by the local Haussa village chief. Judgements are enforced by armed nomad guards. The decisions of the tribunal rarely favor the trespassing herder.

On the other hand, no comparable protection is offered to those who wish to develop the land for purposes of livestock production by improving the pasture of cultivating forage crops. The ultimate effect of this policy is to provide an initiative for the grain producer to expand the area he has planted to grain, since this is the only effective way to gain a private interest in the land. No similar incentive exists for the livestock

producer. There is no means by which the livestock producer can set aside a plot of land as a dry season grazing reserve and enforce his rights when this plot is encroached upon.

If the legal protection currently extended to grain crops during the rainy season were to be extended to producers of forage crops or other inputs to livestock production, the sometimes conflicting demands of grain and livestock production might by resolved. Furthermore, the expansion of the private property rights of livestock producers might stimulate livestock producers to make improvements in the land which would preserve its quality and prevent further desertification. This does not necessarily imply a shift away from the priority goal of supplying sufficient grain for the population if grain production technologies which yield higher returns to land can be implemented.

The following is an example of how such a system might function. An individual livestock-producing household, or a cooperative, would agree to make certain improvements on the land, such as the production of forage. A land management bureau established at the regional level of the Livestock Service could maintain agents at the village level who would distribute grass seeds, provide extension services, and settle disputes over damage done to the forage crop. Such a program would not only preserve, but improve the quality of the land. The extension of private property rights to such individuals or cooperatives would also be consistent with the tenets of Islamic law, as long as some improvements on the land are made.

The household could mark its allotted land by a thorn-brush fence, and the right to an action for damages would arise whenever this fence is breached and the encroaching animals consume the forage which is developing on the plot. In addition to the agreement to make improvements, the only condition which would need to be imposed upon the individual claiming the property interest would be that he not allow his own animals to consume the developing grasses until the latter part of the rainy season. This would ensure that the grasses be allowed to develop and avoid the problems involved in allocating the damages between the owner's animals and those which committed the trespass. Furthermore, the suit for damages could only be brought if the trespassory act occurred during the rainy season when the grasses were developing, up to the time when the owner decided to let his own animals graze on the plot.

Outside of the rainy season, no individual property interest would be recognized and, just as in the case of the grain fields, the land would revert to public rangeland.

This scheme, if effective, might provide an incentive for protecting grasses during the rainy season. The point in protecting the grass cover during the rainy season is to allow it to develop. The rainy season is the time when such protection is most needed, since this is the time when plant growth takes place and when a healthy grass cover can prevent soil erosion. Also, if the grasses are not consumed as they grow, a larger crop of grass seeds would result, and the quality of the range in the following year would be improved.

Such legal protection combined with an appropriate extension program might result in benefits for the producers as well, if it encourages Tuareg mixed farmers to produce forage or to set aside reserves during the rainy season. The linear programming analysis indicated that, as the cattle herd expands, most of the available September labor must be devoted to guarding the animals to prevent them from encroaching on the grain fields and consuming the ripening grain. If the attribution of property rights to livestock producers does stimulate the setting aside of pasture reserves, the labor requirements of livestock enterprises during the critical September period might be reduced by confining the animals to the plot which had been set aside during the rainy season. This would alleviate the September labor constraint, if little additional work is required to confine the animals to the plot.

Another desirable aspect of this alternative is that it provides a system of land management based on existing institutions. There would be no reduction in the rights of grain producers to bring an action to recover damages caused by trespassing herds, although a strong argument can be made for revising the procedure by which such rights are enforced. This approach involves only the extension to livestock producers of rights to bring a similar action. Possibly, the involvement of a Livestock Service agent in the dispute settlement procedure might promote more equitable solutions. In any case, it is apparent that some procedural reform is required at the village level for the approach to be effective.

Several problems must be overcome, in addition to procedural reform, before such an approach can accomplish the goals of resolving property dis-

putes or protecting the environment. The primary problem is that currently there is no system for recording interests in real property. Since the forage plot requires less in the way of obvious improvements than a plot planted to grain, disputes may frequently arise concerning ownership of the interest in a given forage plot. This problem can be resolved partially by stipulating that the interest can only be claimed upon the erection of obvious improvements, such as a thorn-brush fence and the performance of acts indicating an intent to exclude all animals from the plot. Furthermore, the term of the interest should be for only one rainy season, renewable in subsequent years by the maintenance of the fence, improvement of the grass cover and acts indicating the intent to exclude animals.

The second problem is that transit corridors must be maintained for herds moving through the area to northern pastures. This could be accomplished by limiting the areas in which forage plots could be claimed. Again, the lack of a system for recording property interests poses a problem. It may be necessary to have a tribunal at the regional level to apportion lands to each group and to settle disputes over conflicting claims. This would add an unrealistically heavy judicial and administrative burden. A more realistic alternative would be to limit either the allowable compensation for damages or the amount of land which could be claimed for forage crops. This would discourage producers from claiming too large a plot and thus cutting into the land which would otherwise be available for transit corridors. The latter alternative would lend itself more readily to self-administration.

The intention of the scheme is to provide a means of protecting the grass cover during the rainy season and of resolving the conflicting demands of grain and livestock production. The recognition of a limited property interest akin to the interest of the grain cultivator in his land during the rainy season might accomplish these objectives. However, additional information on technical coefficients is required before the feasibility of forage production can be confirmed.

Associated Land Tenure Reforms. -- A problem related to the above is that current property laws in Niger, as they were explained to this author by a local government official, recognize a more permanent interest in land than that mentioned above once a household has planted a given plot

to grain for three consecutive years. The ability to acquire more permanent rights to the land merely by continuing to plant grain is an additional incentive to village-dwellers to continue grain cultivation, even though they have an alternative source of income from trade which makes the cultivation of grain for subsistence unnecessary. These rights must be renewed each growing season by planting, but there is no requirement that the owner continue to cultivate the entire field through to harvest in order to maintain his rights to the entire parcel. Furthermore, the planting requirement may be fulfilled by hiring laborers to plant and weed for the first few months of the season, thus avoiding the need to allocate household labor to these tasks. Then, once the plants have sprouted, the farmer can abandon the field altogether while maintaining his permanent interest in it and his right to sue for damages if trespassing herds encroach upon it.

Alternatively, once a more permanent interest is acquired, the farmer can lease his land to households which are unable otherwise to obtain land, and have his tenants plant and cultivate his parcel. The farmer may demand additional services from the tenant's household, such as assistance with domestic chores or labor on other fields owned by the lessor. The produce from the plot thus loaned is normally the property of the tenant, but the system allows the landlord to maintain his more permanent interest in the property while obtaining additional labor services as a form of rent.

It is obvious from the above description that such practices are in need of reform. The incentive to put land into grain production, even without the intention of bringing the crop to fruition, must be eliminated. While the ability to acquire a permanent interest in land through continued cultivation may provide a necessary and useful incentive for grain producers in the agricultural zone to the south, it is clearly a detrimental policy in the pastoral zone.

Labor-Augmenting Change in Grain Production Technology. -- An alternative approach to relieving the September labor constraint and avoiding the necessity of shifting to less productive grain technologies as cattle herds expand would be to introduce changes in grain production technologies which would increase labor productivity. A simple example of such

technological change would be the introduction of grain varieties which mature more rapidly. This would shorten the waiting period between the August weedings and the October harvests, when fields must be guarded to prevent animals from destroying the crop. The decrease in the labor requirement would enable mixed farmers to complete the harvest earlier, thereby leaving them more time to devote to livestock production. Possibly, the reduction in labor requirements during the harvest season would also prevent having to shift to more land-extensive technologies once the cattle herd expands.

The result of such an effort, however, would be at best to hold constant the area planted to grain by eliminating the need to increase the area planted in order to meet the household's subsistence needs as cattle herds are expanded. On the other hand, such technological changes may even result in an increase in the area planted to grain due to the increase in the relative profitability of grain enterprises. Given the development objectives of encouraging cattle production while restricting grain production, the development of substitutes for household grain production may be a preferable approach.

Developing the Market as an Alternative to Household Grain Production.--The linear programming analysis indicated that Tuareg mixed farmers are constrained from expanding their cattle herds by the desire to produce enough grain to meet subsistence requirements. Although in some cases, profit-maximizing behavior alone would dictate an increase in the cattle herd and the use of the increased income from the larger herd to purchase grain for the household, Tuareg households refrained from doing so due to a lack of confidence in the market, particularly as a source of supply for such an important component of the household diet. It is therefore necessary to build confidence in the market as a source of grain before the development objectives listed above can be attained.

An assured supply of cheaper, high-quality grain to the local market could create greater confidence in the market as a source of grain and thereby increase the relative attractiveness of livestock enterprises. To achieve such confidence, the grain appearing on the market would have to be of comparable quality to the grain produced by the households

themselves and would have to be slightly cheaper and more consistently available than was the case during the survey year. This effectively precludes any effort on the part of the government grain marketing board (OPVN), unless that agency adopts a more realistic storage policy by allowing agents to get rid of rotting and infested grain rather than allowing it to contaminate new grain shipments in the warehouse. It is possible that the paved road which is scheduled to link the Azawak region with the two regional capitals at Agadez and Tahoua will help to assure more regular and less expensive grain supplies from the south.

The Development of Goat Production. -- The goat, rather than the cow, is the basic component of the Bush Tuareg livestock enterprise. The smallest and least wealthy households are likely to own one or two goats, and even the largest Bush Tuareg household strives to maintain a herd of twenty to thirty goats in addition to its cattle holdings. The fact that goats are more common to households in the northern Sahel raises the question of whether development programs for that area should not concentrate on, or at least pay some attention to, the development of goat production. Certainly, if the intention of a development program is to have some immediate impact on the well-being of the least wealthy households, a cattle production project is not in order. Rather, one would anticipate that a project aimed at increasing and prolonging the milk yields of traditionally-managed goat herds would have a greater immediate benefit for a larger number of households, including the least wealthy.

Furthermore, the desire to build up a subsistence herd of at least twenty goats before diversifying into cattle production currently limits the ability of the average household to produce cattle. The subsistence herd of goats is required to assure a supply of milk for the household, since the output of milk from small cattle herds is less certain. An increase in the milk yields of goats might reduce the number of goats required for the subsistence herd, and enable households of average size to acquire and manage the small cattle herd which the linear programs-using model indicates as optimal once the goat herd constraint is eliminated.

Conclusions

The above policy recommendations suggest ways in which the reality of the individual farmer's needs and motivations might possibly be reconciled with development objectives that are in the national interest. The recommendations stem from the basic disparity noted in the previous section of this paper. Although cattle exports are an important source of foreign exchange earnings, although social welfare in the pastoral zone may be maximized by specialization in cattle production, and although continued grain production and uncontrolled land use in that area is resulting in a steady deterioration of the quality of the land resource, extensive grain production is still in the private interest, and individual farmers continue to devote their efforts to grain crops. Few mixed farmers in the pastoral zone find themselves able or willing to specialize in cattle production, or even to increase cattle production at the expense of their grain crops. National objectives may simply be incompatible with those of the indigenous population, most of whom are only peripherally involved in cattle production.

Programs aimed at increasing the attractiveness of cattle production to mixed farmers might have some impact on increasing the number of cattle held by them in the southern pastoral zone. However, it is unlikely that marginal changes in technologies and prices alone will be effective in reducing the area planted to grain and preserving the quality of the land resource. To accomplish such objectives would require structural reforms such as reforms in property law and the development of confidence in the grain market as an alternative to household production. In addition, complementary programs to develop the productivity of goats would enable less wealthy households to reach the position where they can assume the risks associated with cattle production.