THESIS

PASTORAL DEVELOPMENT IN THE SAHEL

Submitted by

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY Gregory Boyce Greenwood ENTITLED Pastoral Development in the Sahel BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF Master of Science.

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ABSTRACT OF THESIS

PASTORAL DEVELOPMENT IN THE SAHEL

Ecological, geographic, economic and anthropological literature pertaining to the Sahel is reviewed in order to provide a basis for pastoral development policy. Great variability in annual primary production is the principal characteristic of Sahelian vegetation. The range can best be improved by increasing the density of woody plants on dry season range. Simple grazing trials are recommended to verify and quantify this improvement. Traditional pastoral systems were found to be well adapted to the great variability of the Sahel. Traditional strategies sought to obtain a consummable output while maintaining a level of risk aversion. The role of commercialization in an optimal strategy is unclear and may depend on the pastoralist's wealth, personal discount rate, perception of future risk and perception of his herd as a risk averting mechanism. Historical events have increased pressure on the resource base while disrupting the traditional social and political structures of the Sahel. Resource degradation and increased household insecurity have resulted. Development projects must change the micro-economic environment of the pastoralist by simultaneously increasing primary production and decreasing risk. A number of ecological and social techniques are discussed. A new type of rural institution is proposed that would unite pastoralists, local government officials and technical experts in developing, testing and evaluating potential solutions.

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1.0 INTRODUCTION

Sahel means "edge" in Arabic and refers to the semi-arid southern fringe of the Saharan Desert in west and central Africa. Extensive subsistence livestock herding, termed pastoralism, has long been a major component of the livelihoods of Sahelian peoples. The region suffered a severe drought in the early 1970's which decimated the herds and impoverished the already poor nations of the Sahel. By 1973 the plight of these nations had attracted the attention of the developed world. The disaster and the subsequent involvement of donor agencies who had no previous concerns in this area prompted the analysis of traditional societies and the critique of previous development efforts.

Since this literature has appeared only over the last decade, with the bulk of it coming within the last six years, it is not surprising that there is much confusion about the Sahelian resource base and the pastoral systems that use it. Two types of literature exist: ecological and anthropological, with occasional articles of a geographic or economic nature. There has been little consensus on such issues as the motivational bases of pastoral behavior or the extent and causes of resource degradation during the drought. Though young, the literature does show an evolution of perspective. An original stance which was critical of traditional systems has been discredited and a revisionist movement begun, seeing rationality in what was previously considered irrational. The diversity of proposed actions, underlining the different perceptions of the proposers, indicates a great deal of uncertainty about what an optimal survival strategy might be in the Sahel.

This paper reviews the relevant ecological and anthropological literature in order to determine the nature of pastoral underdevelopment and to outline approaches for development of pastoral systems. These goals are not different than those of many other papers on pastoralism in the Sahel. However, the paper does attempt to formulate a holistic picture of ecosystem function as modified by human perception and behavior.

Underdevelopment is often linked to poor resource management with low land productivity. The ecological literature on the Sahel is examined in Section 2 to determine if the Sahelian resource base could be more productive than it currently is.

Section 3 outlines the traditional strategies used by pastoralists to exploit their environment. These traditional strategies, though still the basis for pastoralism today, have been greatly affected by the historical events and trends outlined in Section 4. These historical processes have determined the present set of relationships between man, domestic livestock and land. Section 5 considers the possible configurations of these relationships and the consequent nature of the problems confronted by pastoralists. Section 6 outlines a number of feasible activities that would aid in the solution of these problems.

This paper presents an analysis that would serve as the basis for pastoral development policy in the Sahel. As one would expect in a discussion where basic premises are not as yet established, this analysis contradicts or even ignores some of the tenets and conclusions of other analyses. For the sake of brevity, these issues are not argued in the text. It is hoped, however, that through some form of dialectic a more effective and just development policy will emerge.

2.0 THE SAHELIAN VEGETATION AS A RANGE RESOURCE

There are several good general descriptions of Sahelian vegetation (Gillet, 1969; Gillet, 1961; Bille and Poupon, 1972a; Bille and Poupon, 1972b;Le Houerou , 1980). Rather than reproduce the efforts of those authors, this section highlights those characteristics of the vegetation's structure and dynamics that affect its ability to provide quality forage throughout the year. Of particular interest is the extent to which the current vegetation departs from its potential as a range resource. The following subsections outline the different landscapes and communities of the Sahel, the vegetation responses to rainfall, grazing, fire and fertilization, and the value of such vegetation as a grazing resource.

2.1 Sahelian Landscapes and Plant Communities

Numerous classification schemes are possible for the biogeographic phenomena considered here. Whenever possible, schemes that classify the land according to its utility as grazing land, rather than by its floristic or geographic relationships, will be used.

2.1.1 Macro-Landscapes

The Sahel is the transition zone in west and central Africa between the arid Saharan Desert in the north and the humid savanna-forest land on the south. As a transition zone its boundaries are drawn differently by various authors, but the Sahel can be visualized as a band generally 300 km wide (N-S) running E-W across West Africa, centered on the 15^{o} N latitude (somewhat north of that line in the west, south of the line in the east).

Mean annual rainfall (MAR) varies from 100-150 mm in the north to 500 mm in the south. The rain falls entirely during the summer months. In the Nigerian Sahel, Granier (1974) calculated a nine-week growing season, starting in the second half of July, with only two to three weeks of conditions that are optimal for plant growth.

Boudet (1975) distinguished seven different types of Sahelian landscapes, according to topography and soil texture.

1. highly undulating sand dunes
2. sandy peneplains of fairly flat profile
3. sandy loam peneplains
4. low-lying peneplains with clayey loam soil
5. thin sandy soil overlying rock or laterite
6. thin clayey loam soil overlying rock or laterite
7. rock or laterite outcrops

To these seven landscapes, Boudet added the flood-recessional range lands found along the Senegal and Niger Rivers as well as around Lake Chad.

While such landscapes will certainly support somewhat different vegetation, the seasonal availability of water in each landscape determines its value as grazing land. Given the strong seasonal variation in rainfall, Sahelian landscapes can be classified from a management viewpoint as wet or dry season ranges. Wet-season ranges are herbaceous ranges, with or without trees, usable during the rainy season because of water holes and ephemeral streams. Dry season ranges are of two types: those that provide green herbaceous forage throughout the dry season (generally the flood-recessional lands), and those that provide forage in the form of tree leaves and fruits. Water in this second category is pulled from deep wells. The spatial separation of these seasonally distinct ranges is the basis of the transhumant movements noted in the Sahel. Breman et al. (1978) described a transhumant system based on the complementarity of wet season and flood-recessional ranges in Mali and Mauritania, while Bernus (1979) described the Twareg system based on wet season grass and dry season arboreal rangelands.

Few studies on the flood recessional ranges exist in the literature. While not discounting the importance of flood recessional range, this paper will concentrate on the wet season ranges and dry season arboreal ranges. While these ranges occur on all of Boudet's landscapes (with the possible exception of the fourth), the ranges that have received the greatest attention have been in the first and second landscapes: sand dunes or sandy peneplains. Unless otherwise noted, the discussions hereafter refer to these sandy landscapes.

Rippstein and Peyres de Fabregues (1972) sketched what they considered to be the climatic climax vegetation on these sandy soils. In the north would be found a sparse steppe of perennial bunch grasses and sedges (Panicum turgidum, Aristida pallida, Cyperus conglomeratus). In the center would be a brush steppe, with Commiphora africana and Acacia raddiana and an herbaceous cover of annuals (Aristida mutabilis, Schoenefeldia gracilis, Cenchrus biflorus). In the south would be a tree steppe with Combretum and Acacia spp. and an herbaceous understory of perennial grasses (Aristida longiflora, with Andropogon gayanus and Hyparrhenia dissoluta on wetter sites).

The shift in herbaceous life form from perennial to annual to perennial along a N-S gradient is striking and to some extent controversial. Gillet (1960) considered the annual form to be climax, with changes in floristic composition and diversity occurring under grazing. Peyres de Fabregues (1971) concluded that the annual aspect of the Sahel was due to the deleterious effects of fire on perennial herbs. Granier (1975) stated that in the absence of disturbance, the Sahel would have perennial grasses as the understory. A mosaic of annual and perennial forms, controlled by fire and perhaps grazing would appear to be the appropriate model for the herbaceous layer.

2.1.2 Micro-Landscapes

Within all of Boudet's landscapes, slight differences in relief or soil type lead to different micro-landscapes. This local diversity is quite pronounced in undulating sand dunes. These sandy dunes are common in the Sahel and are used as wet season range or have been converted to dry season range by the construction of permanent wells. They have been studied more extensively than other landscapes. To the extent that these sandy areas support trees or perennial grasses yet lack a dry season water source, water development represents a major means of increasing dry season forage production, the major limiting factor in Sahelian pastoral systems (Breman et al., 1978).

Using ordination techniques, Bille and Poupon (1972a) distinguished three major plant associations in the Ferlo, Senegal: a dune summit and slope association, an interdune depression association, and an association found in the shade of trees. Primary production was highest in the depression, medium in the shade and lowest on the dunes (Bille and Poupon, 1972b). On the dunes, the rate of growth was also low (1.2 g m^{-2} day^{-1}). A difference in the duration of water availability between the shade and the depression sites showed that while total production was different at each site, the rates of growth were identical and high (4.3 g m^{-2} day^{-1}). Gillet (1961), working in central Chad also noted 2 to 3 fold increases in production under trees although his absolute values for production were considerably higher.

The synergistic effects of woody species and grasses in arid environments have been noted by others. Noy-Meir (1973) categorizes these effects as atmospheric (reduction or insolation, temperature, wind, and therefore evaporation) and edaphic (increased soil organic matter, higher nutrient concentration, better soil formation via accumulation of windblown sand and silt). In the Sahel, one can hypothesize that trees create a temperature regime more favorable for net photosynthesis and water use efficiency. It is possible that the moderation of temperature allows longer daily periods of photosynthetic activity with attendant transpiration, thereby accounting for the shorter growing period that Bille and Poupon found beneath the trees. Depierre and Gillet (1971) noted floristic differences between the herbaceous cover beneath trees and that found in the open. They noted that the herbaceous species normally found only beneath trees began colonizing the inter-canopy spaces wherever decaying plant material was found, supporting the contention that increased organic matter is a critical factor in the micro-site beneath the tree canopy. Radwanski and Wickens (1967) found higher concentrations of carbon, nitrogen and phosphorus under Acacia Albida (a southern Sahelian species) than in the open, providing a possible mechanism for the greater herbage production found beneath this remarkable tree (Penning de Vries, 1978).

2.1.3 Vegetation Structure

While the major lifeforms of annual, perennial herbaceous and woody are useful for describing the broad patterns of Sahelian vegetation, greater precision is required to follow the vegetation's value as forage and its dynamics with respect to environmental conditions.

2.1.3.1 Woody Species

Virtually all Sahelian tree species have dry season forage value. Diallo (1971) provided an extensive list of these species, the plant organs consumed by various livestock species, and their relative forage values.

The ability to provide dry season forage is an important dimension by which to evalute the worth of tree species. Gillet (1960) classified the woody species in central Chad according to leaf persistence, with Balanites aegyptiaca, Maerua crassifolia, Acacia raddiana, A. nilotica, Boscia senegalensis and Salvadora persica having the most persistent leaves and therefore contributing more to the dry season forage. Acacia mellifera, A. senegal, Ziziphus mauritania and Bauhania spp. had less persistent leaves, while Grewia tenax, Commiphora africana and Capparis aphylla were deciduous. Similarly, Poupon and Bille (1974) noted that some species (Sclerocarrea birrea, Euphorbia balsamifera) leafed out before the rains (i.e.,at a very critical time for livestock), while others (Commiphora africana) awaited the onset of the rains or some other environmental cue. Such differences should be noted, if not managed for, in any range management proposal.

Reproduction of woody species occurs generally by germination (Granier, 1975). Rates of reproduction in some cases are higher under grazing regimes that allow livestock to consume the fruit, thereby scarifying the seed coat in the gut (Gillet, 1960; Bernus, 1977a). Generally, however, grazing is presumed to be detrimental to tree populations, since protection from grazing leads to great increases in the density of woody plants (Depierre and Billet, 1971; Granier, 1975; Poupon, 1977). These effects are discussed in more detail in Section 2.2.2.

2.1.3.2 Annual Herbs

Annual herbaceous forms can be classified according to several major dimensions. These include family (Poaceae vs. Leguminosae), length of vegetative period and habitat.

Legumes of high forage value (Alysicarpus spp., Indigofera spp. Crotalaria spp., Zornia spp.) are found intermixed with the annual grasses and are considered part of the climax vegetation (Gillet, 1960). They generally germinate after the grasses and complement the grass cover as forage by flowering just as most of the annual grasses begin to senesce. The competitive relationship between grasses and legumes is strongly influenced by drought and grazing. Their growing season is of intermediate length (67 $\pm$ 15 days) (Penning de Vries, 1978).

The classification of annual grasses by length of vegetative period shows great diversity and possibly ecotypic variation. Several authors noted a progression in the flowering of Sahelian annuals (Rains, 1963; Valenza, 1970). These annuals have been classified into two groups: short cycle annuals (vegetative periods of 30-50 days) and long cycle annuals (vegetative periods of 60-90 days) (Penning de Vries, 1978).

An important issue is the degree to which the short cycle annuals, the most common Sahelian grasses, completely use available resources to produce forage. Penning de Vries *et al*.(1978) modelled the biomass production of annuals as a function of the rate of growth operating over the duration of vegetative growth. Rate of growth was a function of soil nutrients while duration of growth was determined by soil water status modified by daylength. The authors stated that flowering was a photoperiodic response. Thus, for any given rate of mineralization, biomass is strictly a function of growing period. Their model predicted, and Stoosnijder (1977) verified,that the vegetative growth of annuals on both sandy and clayey soils at Niono, Mali (MAR = 570mm) was completed before the grasses had completely exhausted the soil moisture.

Several interpretations of these results are possible. One might conclude that the short cycle annuals have as long a vegetative period as the annual variation in rainfall will permit. A post-season surplus of soil water in any single year is therefore possible, but does not indicate that over a multi-year period water in excess of the population's needs. On the other hand, the dominance of the typically north Sahelian short cycle annuals in the southern Sahel, where these studies were made, could lead one to conclude that surplus soil water does indeed indicate precipitation in excess of the population's requirement. In that case, one may hypothesize that the lack of long cycle annuals results from the lack of a seed source, possibly because of the elimination of immature plants by grazing. Certainly additional study is needed on these interactions.

There may be some relationship between the length of a grass's vegetative period and its habitat preferences. Gillet (1960) classified grasses on the Ouadi Rime ranch in central Chad according to habitat. He classified most of the short-cycle annuals (Brachiaria deflexa, B. distichophyalla, Cenchrus biflorus, Dactyloctenium aeygptium) as Sahelian heliophytes, not at all resistant to drought. The longer cycle grasses were either semi-coarse, semi-xerophytic species (Schoenefeldia gracilis, Eragrostis spp.) or pseudo-sciophytes found beneath tree canopies (Brachiaria spp., Commelina spp., Urochloa llata, Digitaria marginata, Setaria verticillata).

Reproduction of annual grasses depends on their abilities to produce seed and the fitness of their germination strategies. Bille and Poupon (1974) found in the Ferlo, Senegal that only 2% of the seed produced in a "normal" year was required to reproduce the annual vegetation. Furthermore, one-third of the seeds present in the soil were more than one year old. This hold-over reflected a conservative germination strategy. Granier (1975) reported a germination experiment in which only 46% of the annuals' seeds germinated after 12 days of moisture, as compared with 98% germination for perennial grasses. From these data, one would expect a very resilient annual grass population, and indeed this seems to be the case. Bille (1978) noted that the effects of one bad year (1972) during which no seeds were produced were not noticeable two years later.

2.1.3.2 Perennial Grasses

Perennial grasses are not common in the brush steppe of the Sahel but do exist north and south of the Sahel as drought-resistant forms or as savannah grasses. Attempts to re-establish perennials in the wetter southern Sahel in Senegal have failed (Diallo, 1968). Elsewhere, populations of _Andropogon gayanus_, formerly important in low areas, have been decimated by the drought (Breman and Cissé, 1977). Both Rains (1963) and Breman and Cissé (1977) conclude that _A. gayanus_ is very sensitive to grazing as well. The most commonly encountered perennial grasses, _Panicum turgidum_ and _Cymbopogon proximus_, are respectively a drought resistant species generally found north of the most intensive grazing, and a species considered unpalatable (Rains, 1963). Fire and grazing are seen as the primary agents militating against perennial species in the Sahel (Peyre de Fabregues, 1971). Thus, one can hypothesize that most existing perennial grasses cannot reproduce given the current levels of disturbance in the Sahel, even though they could be considered part of the climatic climax.

Where perennial grasses can survive, they are more productive than annuals (Granier, 1975; Breman, 1975; Penning de Vries, 1978). Higher production in _A. gayanus_ may result from a longer growing period (Rains, 1963) as well as from internal recycling of nitrogen (Breman and Cissé, 1977). However, these very characteristics make _A. gayanus_ particularly sensitive to grazing and drought.

2.1.4 Vegetation Structure and Productivity

While perennial grasses are still important on flood recessional ranges, they are not and probably will not be important on the sandy upland ranges that dominate the Sahelian landscape. On sandy ranges, vegetation productivity and forage value are linked to the density of trees. Beneath the tree canopies, a favorable microclimate and a higher concentration of organic matter allow certain annual grasses to grow faster or perhaps for a longer period leading to greater production. Between the trees, lower producing annuals predominate. The reason for lower production may be lower rates of dry matter production, shorter vegetative periods or both.

Since trees are important forage plants themselves and have been shown to increase under protection, it is reasonable to suppose that the Sahelian vegetation is currently less productive than it could be. It is not clear, however, that higher production is sustainable under any pressure, grazing or otherwise.

2.2 Sahelian Vegetation Dynamics

Having outlined the basic structure of Sahelian vegetation, it is necessary to determine the dynamics of this vegetation, i.e., the changes in floristic composition, structure and production induced by external factors.

2.2.1 Response to Rainfall

Rainfall is of utmost importance in this region since it sets the length of the growing season. Bille (1974) defined the "useful rainy season" as beginning with 30 to 60 mm of rain received in less than 15 days, and continuing as long as monthly rainfall exceeds 40 mm. He further found that biomass could be satisfactorily predicted from the number of days during which soil water reserves exceeded evapotranspiration demands (Bille, 1975). Production in other tropical savannas also depends on the length of the growing season (Bourliere and Hadley, 1970). Daily rates of growth during the growing season are generally 1 to 4 g m^{-2} day^{-1} and resemble those presented by Bille and Poupon (1972b). Higher productions under similar rainfall amounts in winter rain deserts can be attributed to a lower rate of evapotranspiration which effectively increases the length of the growing season (De Wit, 1975).

Soil differences do not appear to affect primary production since communities on different soil types have generally the same production under similar rainfall regimes (Granier, 1974; Breman, 1975). This constancy seems paradoxical considering the degree to which soil texture determines soil water availability (Noy-Meir, 1973). It may well reflect the prevalence of short cycle annuals and the influence of environmental factors other than rainfall on the community composition.

Variations in the intensity, amount and timing of the rainfall affect both floristic composition and production. Patterns of variation in amount of total rainfall are discussed in depth by Bille (1974), Bernus (1977a) and Rippstein and Peyre de Fabregues (1972). Rainy seasons characterized by early rains followed by a prolonged drought do occasionally occur in the Sahel. Such seasons deplete both perennial reserves and annual seed stocks, and produce a sparse cover composed of plants with very short cycles and adaptive physiology (Tribulus terrestris, Blepharis linariifolia). Heavy rains, on the other hand, prolong vegetative growth and give denser cover with the appearance of more southern species (Peyre de Fabregues, 1971). Heavy rains also recharge deeper soil layers shifting the advantage toward deeper-rooted perennials (Gillet, 1960). Medium rains (10-20 mm) every 5 to 10 days favor faster growing annual grasses to the detriment of the slower growing legumes. Thus, for a given total rainfall, many different floristic compositions are possible, supporting the contention of Breman and Cissé (1977) that the herbaceous stratum is too changeable to be of much use in mapping Sahelian rangelands.

The most important and best documented rainfall related event is, of course, drought. Some annuals (Aristida mutabilis, Cenchrus biflorus) respond to drought with shortened vegetative periods and the production of seed, often sterile, by physiologically immature plants (Bille, 1974; Peyre de Fabregues, 1971; Gillet, 1975). Production is, of course, greatly reduced and in some cases, such as in Senegal in 1972, virtually nil (Bille, 1975; Bernus, 1977a).

Sudanian grasses, both annual and perennial, disappeared in many parts of the Sahel during the drought of the early 1970's(Granier,1975; Breman and Cissé, 1977). Their ability to recolonize those areas is questionable since no viable seed stocks remain in the soil (Granier, 1975). Furthermore, their physiological adaptation to the variable annual rainfall appears slight (Diallo, 1971). Their presence in the Sahel may be the result of an invasion of the area during the wetter years preceding the drought.

Drought effects on trees were extensively studied by Poupon and Bille (1974) during the dry year of 1972 in Senegal. They found that leaf production was reduced 50 to 75%, the number of species flowering and the number of flowering individuals per species were reduced, and that fruit production was greatly reduced (88%) or completely eliminated. Bille (1975) noted, however, that while total production was sharply reduced, its value as forage was still sufficient to support some livestock during a year when the annual grasses produced nothing at all.

Mortality rates among trees varied, with some species (Acacia senegal, Guiera senegalensis), older age classes and individuals growing on dunes being the most severely affected (Poupon and Bille, 1974; Bernus, 1977a). Because of these selective effects, Breman and Cissé (1977) found that changes in composition were much less in the woody stratum than in the herbaceous stratum.

Effects of the Sahelian drought on the long-term productivity of sites in the Sahel depends on vegetative lifeforms. Bille (1975) noted that while herbage production in 1973 was much reduced because of no seed production in 1972 and concurrent seed predation, the grass cover returned to "normal" in 1974, two years after the worst year of the drought. In Mali, however, Breman and Cissé (1977) found that production adjusted for rainfall did not return to pre-drought level and suggested that for an unspecified period the drought shifted the nitrogen balance of the study site toward that of a more arid region. Bille (1975) noted that arboreal production was much reduced after the drought because of high mortality among older individuals. He estimated that in the absence of grazing,thirty years would be required for a complete regeneration of the woody stratum.

Rainfall is the most important factor influencing forage production in the Sahel. Le Houerou and Hoste (1978) found a significant linear relationship between mean annual rainfall and herbaceous biomass, such that a 1 mm increase in rainfall led to a 2.5 kg ha^{-1} increase in biomass production. Using this relationship and the distribution of rainfall at Agades in central Niger (MAR = 158.7 mm) variation in rainfall within one standard deviation of the mean (i.e. 2 out of 3 years) can be expected to produce a maximum biomass 113% greater than the minimum. Variation within two standard deviations (i.e., 19 out of 20 years) will cause a maximum roughly 5 times larger than the minimum. This last figure may well underestimate the difference since the minimum rainfall (44 mm) may not allow for any herbaceous production at all. In the southern Sahel, at the Niono Ranch, similar calculations yield maximums of 53% and 145% larger than minimums for a MAR of 570 mm (Breman and Cissé, 1977).

By contrast, the woody stratum production is much less variable. In 1972, when the annual grasses in the Ferlo produced no forage whatsoever, the trees produced 34 kg ha^{-1}, 28% of the mean production of 120 kg ha^{-1}. As Bille (1975) noted, however, this forage production would have been sufficient to insure the survival of a few domestic animals.

2.2.2 Response to Grazing

Sahelian vegetation responses to grazing must be considered within the context of the wet season/dry season distinction made in Section 2.1.1. The wide dispersal of herds during the wet season results in a very low stocking density on those ranges. During the dry season, the herds concentrate on the flood recessional or the arboreal ranges equipped with permanent wells.

2.2.2.1 Dry Season Grazing

Both Valenza (1975) and Peyre de Fabregues (1971) studied the effects of dry season grazing on the arboreal ranges around permanent wells in Senegal and Niger respectively. Their findings are summarized below.

1. Dry season grazing effects are limited to within 12 to 15 km of the well.

2. Perennial grasses within this zone are eliminated within one year of well emplacement.

3. Tree populations are reduced 5% yr^{-1} within 3 to 4 km of the well.

4. Effects are arranged in concentric zones around the well with nitrophilous vegetation near the well (out to 60-250 m). From 250 m to 2.5 km lies a broad zone dominated by Cenchrus biflorus, Dactyloctenium aegyptium, Brachiaria orthostchys. Beyond this zone, the diversity of the vegetation increases as the species that characterize the surrounding range increase in frequency.

5. The density of legumes decreases in the Cenchrus zone, but increases again further out.

The major factors at work here appear to be the following.

1. The soil organic matter increases near the well, encouraging the nitrophilous vegetation nearest the well and possibly increasing the productivity of the annual grasses in the Cenchrus belt. This increase in soil organic matter may as well shift the competitive relationship between the grasses and legumes toward the grasses.

2. Livestock trample and possibly graze new shoots of the perennial grasses. Losses of perennial grass populations via grazing of new shoots would require that the herds graze until the arrival of the rains in the vicinity, thereby grazing the perennials as they mobilize their reserves.

3. Livestock disperse the protected seeds of Cenchrus biflorus toward the well, and possibly destroy seeds of other species by ingestion.

4. Herders prune trees during the dry season, removing reproductive organs and reserves stored in twigs. Little appears in the literature on the effects of timing and intensity of grazing and pruning on Sahelian tree species; this is an important topic for research.

Both Valenza (1975) and Peyre de Fabregues (1971) concluded that while dry season grazing leads to virtual denudation of the soil at the end of the dry season, it does not damage the annual vegetation and may in fact stimulate its growth by fertilization. Perennial grasses are removed by trampling and perhaps grazing of early regrowth. Trees are removed near wells by trampling, breakage, browsing and pruning.

2.2.2.2 Wet Season Grazing

Grazing during the growing season is critical to the pastoral systems of the Sahel. Grazing during this period allows weight gains by animals (see Section 3.3.1.1), but may also severely affect the production and reproduction of individual plants. Such grazing, especially early in the season, has probably contributed to the disappearance of perennial grasses from the Sahel. However, since annuals produce much more seed than that needed to reproduce the population, grazing can reduce the physiological response of individuals without greatly reducing the resilience of the population. Thus, traditional grazing during the wet season probably does not greatly damage the annual grass component of the vegetation.

In much of the Sahel, dispersion of herds reduces stocking rates to low levels. In Niger, calculations showed that before the drought, wet season ranges were grazed at 22-40% utilization (Rippstein and Peyre de Fabregues, 1972). If local overgrazing of grasses did occur, herders would logically avoid that area the next year in favor of more productive ranges, thereby creating a <u>de facto</u> rotation system (Granier, 1975). Some areas with highly productive annual grasses have apparently supported high concentrations of animals traditionally without permanent damage (Bernus, 1977b).

At higher stocking rates, the following effects have been proposed or observed.

1. Seed production in annuals may be reduced (Granier, 1975). This effect, while undoubtedly present in individuals, has not been

demonstrated as important at the population level. Heady (1961) found that unless grazing pressure was extremely high, sufficient seed was set to assure reproduction in the California annual type.

2. Young plants may be trampled and uprooted (Granier, 1975). This effect, like that above, is undoubtedly true, but may not be important, considering the high rates of competitive elimination observed by Bille and Poupon (1974) in the annual grasses as they matured.

3. Perennial grasses disappear and are replaced by annuals (Breman and Cissé, 1977; Halwagy, 1962; Penning de Vries, 1978; Granier, 1974). While this effect is indisputable, its meaning is ambiguous. Some authors find such replacement to be an improvement because of the generally higher forage value of the annuals (Valenza, 1975; Peyre de Fabregues, 1971). The value of the perennials as a usable resource is questionable as well, since clipping experiments on one important species, _A. gayanus_, show that its productivity is greatly reduced by any grazing at all (Cissé and Breman, 1975).

4. Floristic composition within the annuals changes (Breman and Cissé, 1977; Peyre de Fabregues, 1971; Valenza, 1970). _Cenchrus biflorus_ is usually found to be an increaser since its spiny involucre protects the caryopsis from damage and allows wider dispersal by livestock. Both _Zornia glochidiata_, a legume, and _Tribulus terrestris_, a sand burr, are noted as increasers. The mechanism for increases by these species are not clear. Possibilities include 1) very short vegetative periods, thereby assuring reproduction under grazing, 2) seed protection, especially for _Tribulus_, 3) a shift in competitive advantage toward the legume due to grazing of the taller grasses. While they are not the most preferred species, both _Cenchrus_ and _Zornia_ are useful forage plants, a paradoxical result if one assumes that valuable forage plants always

disappear under grazing. In this annual grassland, differential dispersal of seeds and alterations in competitive relationships may be more important grazing effects than the removal of photosynthetic tissue.

5. Woody species are reduced (Peyre de Fabregues, 1971; Bille, 1978; Breman and Cissé, 1977; Halwagy, 1962; Cepierre and Billet, 1971; Poupon, 1977). Some of these studies compared tree population densities as they occurred along transects running radically away from water sources. Others gave evidence of great regrowth in exclosures, even during the drought. Thus, it is not certain that the effects result from wet season or continuous grazing. If the dry season grazing effects of pruning and breakage are generally felt by older trees, threatening both seed production and continued existence, wet season grazing threatens the germinated seeds with trampling and grazing. Thus, Cepierre and Billet (1971) found both young trees and more vigorous older trees in a plot protected for 10 years near Abeché, Chad. Poupon (1977) found that the fencing of wet season pasture in Senegal quickly led to a regeneration of <u>Commiphora africana</u>, suggesting that grazing of new-sprouted trees can severely effect the population.

2.2.2.3 Grazing and Lifeforms

Grazing does not seem to reduce the quantity or quality of forage produced by annual grasses. Peyre de Fabregues (1971) ranked stocking rate third after rainfall and fire, as a factor directing the dynamics of Nigerian ranges. Overgrazing in this type will more likely manifest itself in the poor performance of the grazing animal rather than in the cover of the herbaceous stratum.

Perennial grasses appear to be sensitive to grazing under Sahelian conditions, especially if they leaf out before the annual grasses germinate. Like other grasses, perennials are most valuable while they are green, yet if A. gayanus is typical, their productivity can be reduced by more than 50% by even a single cutting (Penning de Vries, 1978), making them no more productive while considerably less resilient than the annuals.

Grazing can interact with the life cycle of trees at many points: scarification and dispersal of seeds, trampling and grazing of young saplings, breakage by livestock, loss of photosynthetic tissue, reprodutive organs and reserves by pruning or browsing. However, as a lifeform, trees appear to be more resilient than perennial grasses since they still form an important part of Sahelian vegetation. Considering the synergistic effects induced by trees, their inherent value as forage and their response to protection,management for trees could be an important component in improved grazing systems.

2.2.3 Response to Fire

Fires in the Sahel do occur but certainly not as regularly as in the tall grass savannas further south. They generally tend to reduce the proportion of perennials to annuals and change the ratio of grasses to legumes in the annual grasslands.

In Niger, Peyre de Fabregues (1971) found that as the short cycle annuals senesced, the likelihood of fire increased at a time when the long cycle perennials had not yet completely replenished their reserves. He gave fire as the reason for the typically annual grasslands between the 15^{o} and 17^{o}N latitudes, stating that north of 17^{o}N, the Panicum turgidum tufts were so sparse that a fire could not spread, while south of 15^{o}N, millet fields intervened as fire breaks. He cited as proof the existence of an unburned and ungrazed range in Niger with a relative abundance of perennial species.

Valenza (1970) found that late burning of a grass/legume mixture led to an increase in the grass and a decrease in the legume the following year. The effect was opposite to that of mowing and Valenza suggested that alternating mowing with burning would maintain the composition and allow the production of a good quality hay.

2.2.4 Response to Fertilization

Results from a project, Primary Production in the Sahel, appearing in several papers (Penning de Vries _et al_., 1978; Penning de Vries, 1978; Penning de Vries and Heemst, 1975) have shown the importance of nitrogen and phosphorus in the response of Sahelian vegetation. In particular, the results show the following.

1. With adequate fertilization of N and P, annual grass production increases 3 to 5 fold.

2. Nitrogen is often limiting on sandy soil, while phosphorus often limits production on clayey soil.

3. Degraded soils with soil crusts and no vegetative cover have very high amounts of available nitrogen, which is absorbed by herbage if the soil is tilled and seeded.

4. Inputs to the nitrogen cycle via fixation by unfertilized legumes (_Zornia_, _Stylosanthes_) are significant and can be increased 2 to 3 fold with phosphorus fertilization.

5. Both fire and grazing represent important losses to the nitrogen cycle and as such tend to decrease the productivity of the annual grasses.

In terms of the natural vegetation, these results may provide a mechanism for explaining the high rates of growth under trees since Radwanski and Wickens (1967) showed higher concentrations of N and P under a tree canopy than in the open.

Higher production in annual grasses is not an immediate improvement in range resources since it is a lack of proteinaceous material during the dry season, not the wet season, that generally limits animal performance (Breman et al., 1978; Valenza and Fayolle, 1965). Stoosnijder (1977) suggested that phosphorus fertilization could lead to a good hay field by stimulating legumes which, in turn, would increase the nitrogen input to the grasses. The results of tillage and seeding on degraded soils shows that rehabilitation of degraded lands could also be a feasible means of expanding the resource base.

2.3 The Potential for Higher Production

The replacement of perennial and long cycle annuals by short cycle annuals and the loss of trees are grazing effects that have reduced the value of the vegetation as a grazing resource. Therefore, every pastoral development project should consider both the extent to which these processes have operated in the project zone and the measures that could be taken to increase the production of quality forage throughout the annual cycle.

For grazing systems relying on dry season ranges of trees and annual grasses, range improvement is synonymous with increasing the number of trees. Since trees are the major source of protein during the dry season on these upland areas, a release of the protein constraint on animal performance must come by way of increasing the tree vigor and reproduction. An increase in tree cover would have the additional effect of increasing herbaceous production beneath the canopy, thereby increasing the amount of energy available to the animals during the dry season as well. Given the more consistent production of trees with respect to variations in rainfall, increased tree cover would mean an increased survival rate for livestock in the event of a drought.

While it is clear that protection will increase tree cover, it is not clear that the improved vegetation can withstand grazing pressure without reverting to its present condition. In this regard, the following questions are worthy of research.

1. What rate of stocking balances animal performance with woody generation and primary production during the wet season, during the dry season?

2. How do stocking rates interact with stochastic rainfall patterns in determining woody and herbaceous plant production and survival? How much can heavy rainfall compensate for heavy grazing?

3. What alternatives, other than trees and shrubs, are available for dry season forage?

The first and second questions could most easily be answered by field experiments and construction of a simple model simulating the effects of grazing intensity on animal and vegetation performance. Such a model would be run with random rainfall patterns to determine optimal stocking rates at specified levels of risk of vegetation damage.

One alternative to range vegetation as dry season forage is hay cut during the wet season and conserved. The project Primary Production in the Sahel has shown that light application of phosphorus to grass and legume mixture will allow the efficient production of hay. Such a supplement could reduce grazing pressure in the woody species at the beginning of the wet season, aiding in their regeneration.

While it appears possible to increase the supply of dry season forage, the most important technical question is the economic feasibility of range improvement. This question can only be approached within the context of the pastoral economy.

3.0 TRADITIONAL SAHELIAN PASTORAL SYSTEMS

This section outlines some of the important technical and economic characteristics of traditional Sahelian pastoral systems. Non-traditional activities such as commercialization are examined in order to determine their economic rationale. Much has been written about these pastoral systems from geographic, economic and anthropological perspectives. Bibliographies of these works include Bernus (1975), Baumer and Bernus (1979) Bellot and Bellot-Couderc (1978) and Ergas (1979). An excellent overview of these systems is provided by Swift (1979). The locations of peoples and places are shown in Figure 1.

Before colonization, traditional pastoral systems maintained a long-term equilibrium between man, animals and resources (Baker, 1973; Swift, 1977a). The continued existence of these systems over historical time testified to this equilibrium. This equilibrium was characterized by ecological resilience, rather than stability. Populations, human and otherwise, fluctuated because of war, famine, disease and drought, yet mechanisms existed which allowed the continued interaction of the populations (Holling, 1973)*. The weakening of this resilience by recent changes has been debated (Kates _et al_., 1979)and will be examined in Section 4.0.

Many articles mention "non-economic considerations" or "social factors" that intercede in the behavior of pastoralists. Much of the recent research shows that the ecological and economic systems are generally the principal determinants of the social and political configurations of the societies and not the inverse (Ketalaars, 1978; Dahl and Hjort, 1976a). Thus, when social values are mentioned here,

* The lack of ecological stability might well have been the reason that early officials considered the pastoral systems inefficient.

it is to show their economic value as adaptations to the pastoral environment.

Historically, pastoral societies in Africa have been quite dynamic and adaptive (Fumagalli, 1978), with political and social ties being severed in the pursuit of different economic possibilities. Much of the political change internal to the Fulani peoples in northern Nigeria can be traced to the need of assuring access to pastoral resources (Stenning, 1959; Van Raay, 1975). Thus it appears that when pastorals are presented with new economic opportunities at least some cultural values are expendable. Analysts who have attributed the failures of development projects to traditional values may have failed to see the economic rationality embodied in these values.

Finally, this outline is, of necessity, that of an "ideal type" pastoral system. A number of different pastoral systems exist in West Africa (Swift, 1979). Livestock, especially cattle, are often owned, if not raised, by sedentary farmers as well. Consequently, one finds, in many regions, varying mixtures of economic activities (Fricke, 1975; Van Raay, 1975) that use some but not all of the elements described below. These departures from the ideal type may be indicative of the local physical environment or of the role that livestock play in that particular region. Certainly, any proposal must be based on the local realities and not continental scale generalities.

As a production system, pastoralism combines labor and resources, and through the use of technology, produces an output. Pastoral resources have already been considered in Section 2.0. In the following sub-sections, some important features of pastoral labor, technology and output are considered.

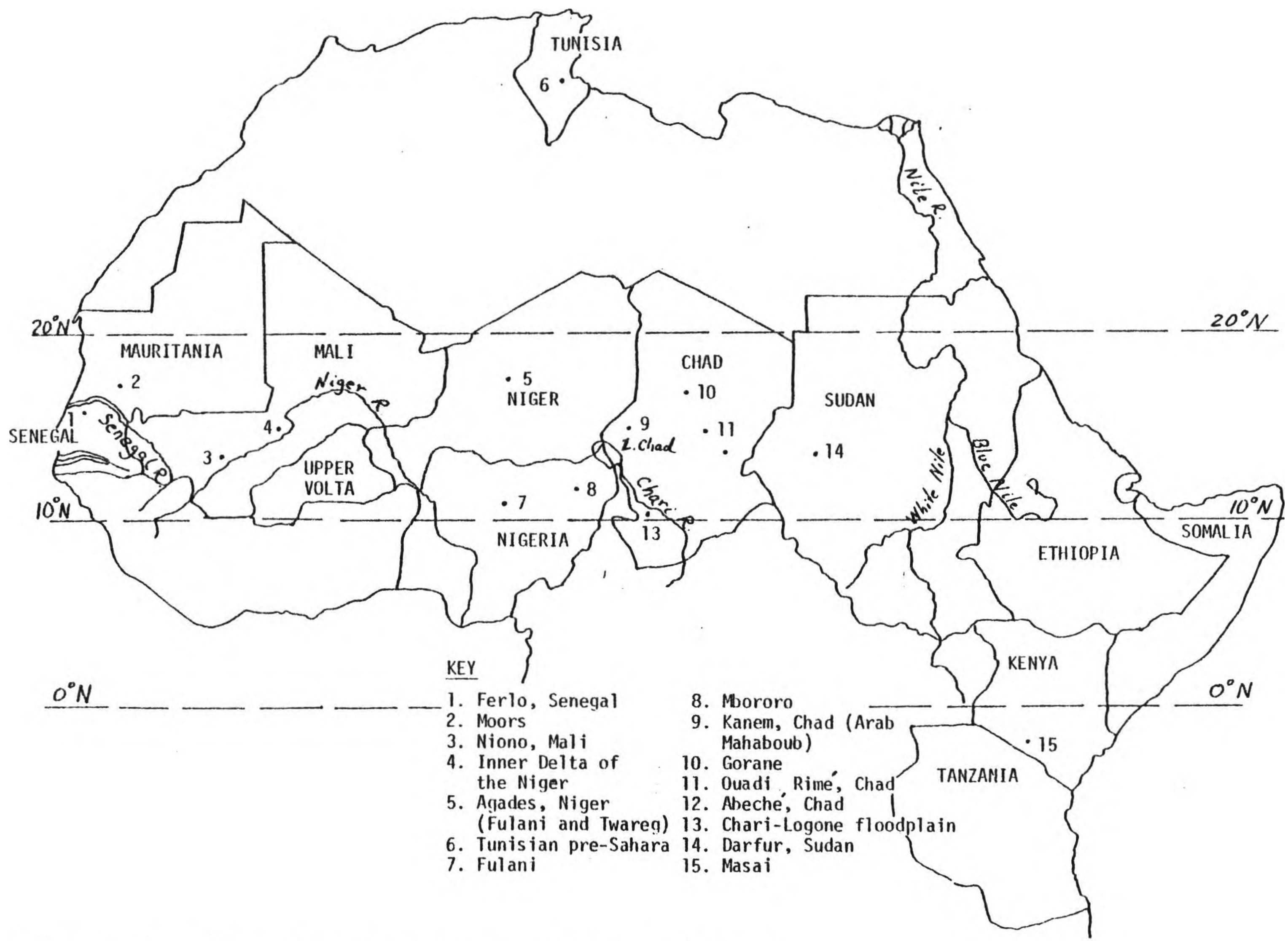

Figure 1. Nations, Peoples and Places Noted in the Text

3.1 Labor Requirements, Accessibility, and Productivity

Most authors find the household to be the most common herding unit. A household exists in a symbiosis with the animals under its management. The herd must be large enough to produce consumable output for household, while the household must be large enough to care for the herd. This simple relationship has several implications.

Swift (1979) proposed that pastoral output was largely insensitive to labor inputs and was more a function of the highly variable primary production. Under such conditions, rapid family growth would be maladaptive, since the human population would often outstrip herd production. Swift proposed several mechanisms that could serve to control pastoral population growth and presented convincing evidence that pastoral populations do in fact grow more slowly than ethnically similar agricultural people (Swift, 1977a, 1977b).

If range conditions permit herds to grow so large that the family cannot provide sufficient labor, additional labor can be obtained through institutional devices, such as adopting or borrowing labor from a poorer family, or by contracting herdsmen who are paid in kind (Van Raay, 1975; Helland, 1978). Polygamy and bridewealth are other institutions that restore the balance of labor and herds by creating new household units to manage the herds within the lineage structure (Van Raay, 1975; Dahl and Hjort, 1976). Though no apparent economies of scale are realized by larger families with larger herds (Swift, 1979), they may realize a significant reduction in the variability of production since households within the extended family can exploit different niches and habitats.

A second strategy that tends to reduce variations in production is that of herd diversification. The pastoralists who would herd different species within a family structure must be able to provide the additional labor required. Cattle do not require a great deal of supervision, but do require considerable labor for watering. Small ruminants however require greater amounts of supervision (Swift, 1973; Dahl and Hjort, 1976). The institutional means for organizing labor-adoption, polygamy, contracts-may all be used to allow herd diversification.

Swift (1979) calculated the caloric return to both land and labor under dryland agriculture and pastoralism. He warned that his figures were first approximations at best, but they were illuminating nonetheless. Comparisons of land productivity could only be realistically calculated for areas where both pastoralism and agriculture were practicable. In that case, Swift's calculations showed that agriculture was clearly more productive. Pastoral labor productivity, however, was from 3 to 10 times higher than that of agricultural labor. Pastoralism has other costs (large capital requirements, greater risks, seasonal mobility and isolation)but its attraction as a way of life is easy to understand, especially in economies where land is not constraining and for people whose culture has inured them to the hardships of the lifestyle.

3.2 Technology

Space precludes exploring in depth all the techniques used by Sahelian pastoralists. The techniques examined below are those that most clearly show the ecological and economic adaptations within pastoralism.

3.2.1 Herd Diversification

Households often own and herd several different species of animals. Such a technique has several advantages.

1. Risk aversion: Herding several different species which utilize different components of the vegetation reduces the risk of loss to drought or disease (Swift, 1973; Bernus, 1975).

2. Stabilizing subsistence output: The different reproductive cycles of goats, sheep and cattle allow a manipulation of reproduction such that milk production is more even throughout the year. Goats offer a particularly interesting advantage, in that birth and milk production during the dry season do not reduce the animal's fitness (as it does for sheep and cattle) since browse is relatively abundant in that season (Swift, 1979; Dahl and Hjort, 1976).

3. Increasing resilience: Physiological responses of goats are such that goat herds produce milk sooner after a drought than do other animals (Dahl and Hjort, 1976).

4. Increasing resilience: Small stock can be converted to small amounts of cash without making inroads on the main subsistence herd (Stenning, 1959; Dahl and Hjort, 1976). Furthermore, their low cost and high reproductive rates make small stock rearing with eventual reinvestment in larger stock the easiest way to reenter pastoralism after a disaster (Dahl and Hjort, 1976).

These observations seem to make small stock the preferable species from a production viewpoint. In fact, Wilson (1977) found that because of range deterioration and increasing sedentarisation over the last twenty-five years, herders in Darfur, Sudan had drastically altered the composition of their herds toward greater numbers of goats. On the other hand, small stock do require more labor and are more susceptible to disease, making them a riskier enterprise (Dahl and Hjort, 1976).

Thus, while greater production is an important motive for diversification, the risk aversion so afforded should not be minimized. Bellot and Bellot-Couderc (1979) noted that people who maintained diversified herds survived the drought of the early 70's more successfully and maintained their livelihood as pastoralists.

The greatest constraint on herd diversification is that of labor. As noted above, different species require different amounts and types of labor. Spatial separation of the appropriate ranges and the provision of salt also require additional labor (Bernus, 1975; Dahl and Hjort, 1976).

3.2.2 Large Herds

Perhaps the most consistently criticized aspect of pastoral economy is the insistence on having as large a herd as possible, or more precisely, on holding many apparently unproductive animals. However, research has shown that the maintenance of large herds is a rational strategy. The advantages appear to be the following:

1. Increased subsistence output: Milk output varies seasonally with a scarcity during the dry season. A larger herd will reduce but probably not eliminate this scarcity (Dahl and Hjort, 1976). To make good this shortfall, animals must be slaughtered, or sold for grain. A larger herd can better support this periodic offtake without threatening the reproductive base of the herd.

2. Risk aversion: While Dahl and Hjort (1976) have calculated the minimum number of animals needed to support a household, it is clear that in a stochastic environment, additional animals represent increased security. During difficult times, animals from a larger herd can be sold or slaughtered without prejudicing the herd's ability to reconstitute itself. Some of the animals normally assumed to be unproductive (e.g. older females) are maintained in the herd because they have a proven resistance to disease and poor nutrition and could provide the basis for a new herd if disaster strikes (Hjort, 1976a). The major

weakness of this strategy is the vulnerability of this form of savings to environmental fluctuations.

Labor availability may be a constraint to larger herd sizes. Dahl and Hjort (1976) note that watering a large herd and supervising it in dense vegetation are the functions that are constrained by labor availability. Thus, the feasibility of owning large herds depends on the existence of the labor exchanges noted in Section 3.1.

3.2.3 Stock Redistribution

Just as labor may flow between households, so may animals be redistributed through various lending or bequeathing institutions (Stenning, 1959; Hjort, 1976a; Van Raay, 1975). Some of the advantages of these transfers are noted below.

1. Increased household viability: In the short run, the receiving household benefits from the increased milk output, and perhaps by the addition of calves to the herd.

2. Risk aversion: In the long run, stock redistribution forms a network of social obligations that serve as a form of social insurance (Hjort, 1976a). Those who loan animals to the temporarily less fortunate can expect to receive similar help should disaster strike them. These exchanges may be seen as a form of investment in which excess animals are converted to long term security in the form of social relationships (Baxter, 1975). In this context, the definition of the household as the basic herding unit is incomplete since its long term viability is assured only by its relations within a larger social unit.

3.2.4 Access to Pastoral Resources

While the free-range concept has some validity in discussions of Sahelian range use, it is important to see that access to pastoral resources has never been certain historically and has been the root of much of the political history of the Sahel. The participation of many Mbororo in the Fulani jihad of the 1800's in northern Nigeria has been explained as a reaction to restricted access to pastoral resources under the Hausa kings (Van Raay, 1975).

Furthermore, the lack of individual land ownership usually meant that resource use was organized at some higher social level. Swift (1979) distinguished two general forms of territorial organization in West Africa. The first form of territorial organization was based on a clan structure wherein membership in the clan conferred grazing rights in a certain territory. Non-clan members used these ranges under certain conditions set by the clan leadership (e.g. payment of tribute). Exclusion of other peoples was finally effected by threat of force. This form of land use was practiced in those areas with a long continuous history of occupation, i.e. in the northern Sahel which the Moors, Twareg and Gorane had long controlled, and in the southern Sahel where agricultural communities were strong enough to extract tribute from local pastoralists (Stenning, 1959) or where pastoral peoples had gained political power (Swift,1979). Although the strength of these systems varied with the ability of the entire economy to generate a surplus, Swift,(1977b) stated that in general, these lineage based systems were not strong.

The second system of territorial organization was based on the creation and control of water points, the key to range use. This system was characteristic of zones of contact between existing power centers where several pastoral groups coexisted. Access to water in Africa is still an effective means of land use control, often involving political maneuvering and inputs of labor (Helland, 1978).

The lack of title to land was probably less the result of a hallowed tradition and more one of the marginal value of land. One can hypothesize that if the marginal value of land were high enough, a system of regulated use would evolve, as it has in agricultural areas. Regulation of pastoral land use did in fact occur in the inner delta of the Niger in Mali during the 1800's. An elaborate code, the dina, was established by Sheik Amadou as a means of assuring access for the Peulh to the important flood recessional pastures of the delta,at the same time reducing the potential for conflict with the resident population (Gallais, 1975). Swift (1979) credited the dina and its organization of agriculture and pastoralism with allowing population densitites in the delta that are five times higher than those found in ecologically similar areas.

Thus, these two systems, lineage-based and water-based, defined access to pastoral resources. These resources, divided into wet and dry season ranges, were generally exploited using the strategy of transhumance. Transhumance had several advantages. Shapiro (1979) listed these as obtaining adequate forage, water and salt, reducing conflicts with farmers during the growing season, providing access to markets and seasonal employment, and allowing social gathering. It is important to remember than any proposed change in the transhumant calendar would have repercussions on all of these advantages and would not necessarily result in a net benefit.

Transhumance permits the exploitation of at least four different range types over an annual cycle: wet season pasture, crop residues, arboreal pasture, and flood recessional pasture.

Wet season pastures provide the critical green forage needed for herd growth and production. Herds are generally more dispersed at this season (Ketalaars, 1978) and their effects on the vegetation negligible. Often herds are forced by a lack of water to leave these ranges before they are completely used (Breman et al., 1978), thus conserving some soil cover and allowing seed set. However, wide dispersal is not always the case. Van Raay (1975) noted that among the Fulani in central Nigeria, wet season with its higher carrying capacity range was the preferred time for social gathering. Similar concentrations of animals during the beginning or height of the wet season were noted by Bernus (1979) and Hissein (1977). It appears that wet season dispersion may be the rule for systems with high capacity flood recessional dry season pastures. For systems with low capacity dry season pasture, one finds evidence for concentrations of animals at some point during the wet season, with the dry season concentrations being determined by the number of available water sources. Considering the hypothesized effects of wet season grazing (Section 2.2.2), the different seasonal concentrations of animals under each system may lead to quite different environmental effects. Only local studies will allow accurate conclusions.

In some pastoral systems, crop residues are an important source of fodder used before the dry season range. Van Raay (1975) stated that crop residues in northern Nigeria were consumed until February, four months into the dry season. Their use prevented higher animal mortality in the late dry season. Though considerable benefits from grazing crop residues could accrue to both the herder and the farmer, the potential for crop damage, conflict and expensive litigation (Horowitz, 1972) may reduce the real utility of crop residues.

Dry season pastures are defined by the availability of water. Stenning (1959) stated that a steady supply of water during the dry season had greater importance than available forage as a criterion for dry season pasture among the Mbororo. Away from the flood recessional pastures, wells are the major sources of water. Fire is perceived by herders as a major problem, destroying a large portion of the forage available to livestock during the dry season (Stenning, 1959; Van Raay, 1975). Tree leaves and fruits assume greater importance as forage during the dry season (Stenning, 1959; Van Raay, 1975; Swift, 1979).

The dry season is difficult for both livestock and herder and the major role of the dry season pasture is simply to maintain the animals with a minimum of mortality until the rains arrive again. A logical strategy would be to graze those areas most distant from the well first while the animals are in better condition, moving closer to the well as the dry season progresses. Such a system generally is not used, probably because of the impossibility of protecting the inner pastures. Consequently one finds the animals obliged to travel the greatest distances when they are the weakest, reducing production and increasing mortality.

Flood recessional lands and other low-lying areas are very important resources wherever they occur. In places such as the Senegal River Valley, the inner delta of the Niger, and the Logone-Chari floodplain in Chad, the ability to provide green growth during the dry season is the basis of the pastoral system (Breman _et al_.,1978). Other run-on areas may green up before the annual grasses germinate, giving forage at the most critical period of the year.

The traditional transhumance routes in Africa have evolved over centuries. It is unlikely that any development project that would reduce this movement could provide equal access to pastoral resources throughout the year (Fumagalli, 1978). Indeed, as Clanet (1977) noted in Chad, people that relinquish transhumance suffer much greater losses during droughts.

3.2.5 Contingency Strategies

The foregoing sections have outlined strategies by which pastoralists obtain an output from their animals while reducing the fluctuation of that output. A critical weakness in pastoralism is that the surpluses of milk and animals cannot be invested and are very vulnerable to loss. Thus, a lifetime's work reflected in a large herd can be quickly destroyed as the last drought illustrates so well.

Other pastoral societies such as the Basseri in Iran have chosen to invest their surpluses in land, which rarely has as high a return as livestock but is however less vulnerable to environmental fluctuation (Dahl and Hjort, 1976). In Africa, the trend is exactly the opposite with surpluses from agriculture being invested in livestock (Horowitz, 1972).

Emigration in the face of disaster is a common strategy among pastoral peoples (Kates et al., 1979; Bernus, 1977; Horowitz, 1977a; Bellot and Bellot-Couderc, 1979). In the case of the Twareg, emigration was nearly a rationalized maneuver, with Twareg leaders historically maintaining contacts in central Nigeria, so that in the event of a drought in the Sahel, access to Sudanian pastures, agriculture and urban employment was assured (Swift, 1977a). The timing of emigration is critical. Fulanis near Agades, Niger moved south very early in the drought and preserved their herds while the Twareg, who remained near Agades, lost most of their animals (Bernus, 1977a).

Agriculture, a part of many pastoral economies, is an important alternative for those pastoralists who have lost their animals and have no means of obtaining breeding stock (Johnson, 1975; Kates et al., 1979). While in general, sedentarisation is a temporary means of reconstituting a herd, permanent sedentarisation with or without a pastoral component has been an ongoing process, especially among the Fulani (Van Raay, 1975; Bellot and Bellot-Couderc, 1979).

3.2.6 Environment and Technology

This brief overview of pastoral technology underlines the variability of the environment, both spatially and temporarily, as the major force directing the configuration of the pastoral system. The resulting adaptations both within and among households to reduce the likelihood of loss and to mitigate the effects of a loss when it does occur illustrates the rationality of pastoralists.
While animal husbandry techniques and mobility are important at the household level, the maintenance of a social fabric via labor and animal transfers maximizes long term survival.

3.3 Pastoral Output

Shapiro (1979) classified the output of herds into four categories: production of animal products, inputs to crop production, financial services and cultural maintenance. The first and third categories (animal products and financial services) are examined in this section. The second (inputs to crop production) is not yet important in Sahelian pastoralism, while cultural maintenance is assumed to have some long term economic value.

3.3.1 Herd Performance and Dynamics

This subsection will consider the performance of individuals and the herd under management as described in Section 3.2.

3.3.1.1 Herd Nutrition and Performance

Grazing studies by Valenza and Fayolle (1965) and Denis and Valenza (1970) show that animals pastured on annual grass-legume plots lost considerable weight during the dry season, but grew very rapidly during the wet season. The gains registered during the wet season more than offset the dry season losses, leading to a small annual increment of growth. The high rates of growth during the wet season (0.9 kg day^{-1}, Valenza and Fayolle (1965)) indicate that the animals have a high genetic potential for growth. Realization of this potential is hindered by poor nutrition during the dry season.

Breman _et al_. (1978) reported that animals in a flood-recessional system in Mali were able to maintain their weight during the dry season because of very selective grazing. In all three studies, protein content of the dry season forage was the factor limiting herd performance.

Most pastoral herds operating on dry season arboreal pastures probably perform somewhere in between the level noted in the Senegalese and the Malian cattle. The cattle used in the Senegalese experiment did not apparently have access to the high protein leaves and fruits of woody species as do pastoral herds. On the other hand, intake by pastoral cattle may be less than that in Senegal since they must spend more time walking to graze and are watered less often (Riviere, 1975).

This generally low level of nutrition is reflected in the animals' late starts of reproduction (4-5 years) and their low fecundity

(60-70%),(Ketalaars, 1978). Improvement in reproductive performance can be expected with improved nutrition (Rains, 1978).

3.3.1.2 Losses to Disease

Livestock diseases have always been important constraints on pastoral production in Africa. The timing and direction of moves in the transhumant cycle often reflect a desire to avoid parasites and insect-borne diseases (Van Raay, 1975). While vaccination campaigns are mounted in Sahelian countries, their coverage is far from complete and many endemic diseases remain uncontained (Ketalaars, 1978; Horowitz, 1977). Mortality among calves is an especially serious problem with losses approaching 40% (Ketalaars, 1978; Shapiro, 1979; Van Raay, 1975). Swift (1979) calculates that a reduction in calf mortality could more than double herd growth rates.

3.3.1.3 Herd Offtake and Rate of Return

While the offtake of any particular herd depends on the behavior of its owner, several studies have shown the current commercial offtake to be between 11 and 13 percent per year (Sabry, 1972; Shapiro, 1979). These figures show that the offtake is near the maximum allowable under current conditions. In Mali, the real growth of the herds (2-3%) roughly parallels that of the population (Ketalaars, 1978). Thus, it does not appear that, considered as a homogeneous population, herd owners are hoarding large numbers of excess mature animals. Shapiro (1979) has calculated that if half of the male animals currently over three years old were removed from the Sahelian herd (10×10^6 head), about 500,000 head would be available the first and after that, only 100,000 animals would become available each year. Such an increase in offtake represents neither an important reduction in grazing pressure nor a great increase in the supply of marketed animals (Shapiro, 1979).

While the performance of the herds and the level of risk in pastoralism leaves much to be desired, the rate of return to capital is still very attractive. Delgado (1979) calculates a rate of return as the offtake plus milk production plus net herd minus operating expenses. These calculations show that on a Voltaic farm with relatively high labor costs, a male animal gives an 8% return, while a female gives 21%. With pastoral labor being relatively more available than farm labor and a pastoral herd consisting two-thirds of females, the rate of return is roughly 17%, approaching the 20% opportunity cost of capital used by Shapiro (1979)*.

3.3.2 Animal Products

Milk production is the major consummable output of Sahelian herds and is the focus of pastoral management (Van Raay, 1975; Stenning, 1959). Two areas of potential improvement in milk production are commonly noted.

First, as previously mentioned, there are great seasonal variations in milk production. Due to shortfalls in dry season milk production, herders are forced to either slaughter "excess" animals for meat or to sell the animals. Second, consumption of milk by humans of necessity denies some milk to calves, reducing the rate of growth of the calf and the herd (Dahl and Hjort, 1976; Rains, 1963).

While one might be tempted to introduce modern dairy techniques, Stenning (1959) pointed out that Fulani cattle are multi-purpose animals selected to produce some milk under the difficult conditions

*This figure seems high. It may in fact be the interest rate paid by borrowers from commercial banks. The investor with small amounts of capital probably gauges the opportunity costs of all other investments as equal to the return obtainable from a herd.

of the transhumance and the variation in nutrition. Unless the environment can be changed, such animals will remain the optimal milk producers.

Slaughter of male animals is one alternative that herders use when milk yields drop below a minimum level. When the shortfall is not severe, sheep and goats are usually slaughtered. Slaughter of cattle is reserved for severe emergencies or for ritual situations (Dahl and Hjort, 1976; Van Raay, 1975). Ritual slaughter tends to reinforce the social standing of the donor of the animal while providing food to the whole community.

3.3.3 Commercialization and Financial Services

Herders have often been characterized as living outside the framework of a money-based economy (Monod, 1975), but their isolation seems to be illusory. Swift (1979) reviewed a number of West African pastoral household budgets and concluded that pastoralists fall in the partly commercialized category with 25-50% of their gross returns coming from sales or barter. Commercialization is an important part of many pastoral economies because the exchange of animals for grains yields from two to sixteen times more calories than does eating the animals themselves (Swift, 1979). Thus, commercialization or barter currently appears to be an integral part of the pastoral economy.

However, as Swift mentions, current levels of commercialization are likely to be considerably higher than those found 30 or 40 years ago, testifying to the growth of commercial economy in Africa. The effects of commercialization and its ultimate value as a survival strategy for Sahelian people will be examined in Section 4.0. The section considers the extent to which herders conform to the economic model of man.

Several authors present evidence that suggests that herders are price responsive. Swift (1977b) found great increases in livestock sales in the 1950's in Somali, which he attributed to the growing purchasing power of Saudi Arabia. Sabry (1972) gave figures from the Agades market that showed sheep sales tripling in two years because of increased demand in Libya. Shapiro (1979) examined price structures for animals of different age classes, the costs of capital and labor as well as the risks of mortality, and concluded that herders generally sold their animals at the optimal age given local conditions (3-4 years). While Sabry's finding shows a price response, it is not known to what extent local herds were destocked of "excess" animals. Shapiro's finding as well does not prove that Sahelian herds are fully exploited commercially, only that when individual animals are sold they are sold at an optimal age.

Swift (1979) did find evidence in Niger Fulani and Twareg structures of very high sales of younger animals. While such a finding could complete the argument on complete commercialization, Swift noted that these herd structures differed from those of more southern Fulani. Furthermore, the figures on herd structure were collected in Niger after several years of drought and may have reflected a contingency strategy in time of drought. Dahl and Hjort (1976) noted in East Africa that offtake rates were higher in herds found in poorer grazing areas and owned by poorer households. They concluded, as one might from Swift's data as well, that the sale of animals was motivated by an immediate need for cash and not by a desire for maximum financial return. Indeed, sales without reinvestment in the herd represent a reduction in long-term security.

The conditions under which commercialization of animals excess to reproductive needs represents a rational survival strategy depend on the wealth of the herder. It appears that the marginal position of poorer herders obliges them to sell an interest-bearing asset to meet current needs, and they do so in an optimal fashion. Lacking conclusive data on commercialization according to class, one can only hypothesize the behavior of wealthier herders. They may liquidate some of their excess animals but not all because:

1. Some males additional to the 4-5% usually noted are required to insure reproduction of the subsistence herd in a risky environment.

2. The herder feels some desire to commit animals to the stock distribution system.

3. Few opportunities exist for the reinvestment at equal rates of return of the money gained in sale.

On the other hand, wealthier cattle owners may market an increasing number of animals if they have an increasing desire to consume. This behavior may imply a higher discount rate, a different perception of the herd as a risk aversion mechanism, and an insulation from the traditional pastoral society.

Given the existing micro-economic data it seems impossible to determine if herders are acting rationally in a commercial sense since the definition of a rational strategy is itself not clear. It is useful, however, to postulate that herders like other producers seek to maximize current income while maintaining a certain level of risk aversion. Factors that would alter the composition of the optimal strategy would include current herd size, current perception of future utility and current perception of the herd as a form of risk aversion. An inquiry using a farming systems approach would give a more objective means of determining an optimal commercial strategy as it is embedded within an overall survival strategy.

3.4 Pastoral Behavior

This brief review of pastoral systems stresses those techniques and forms of behavior that have made pastoralism an ecologically and economically viable livelihood. As such, these techniques provide a set of dimensions by which to judge the effects of recent changes and the current state of livestock owning and herding.

Pastoralism can best be viewed as a set of strategies that allow a human population to exist in a low-producing and risky environment. The basis of this existence is a milk-producing livestock population. A host of strategies have evolved to increase the survival chances of the human population by reducing the impact of environmental fluctuation. A first-order series of strategies involve reducing the impact of fluctuations of the milk output of the herd as a whole (e.g. herd diversification, transhumance). For situations in which impacts can not be avoided, second-order strategies have evolved that optimize household viability (e.g. slaughter or sale of non-milk producing animals, transfers of labor and animals between households, reversion to agriculture or commerce, emigration, and demographic controls). The social network defined by the flows of labors and animals in some cases has been large enough in the past to allow for some assurance of access to the basic forage and water resources necessary for the maintenance of the livestock population. The balancing of labor and animals may have led to a distribution of wealth that, while not egalitarian, was not extremely unbalanced (Swift, 1979; Dahl and Hjort, 1976).

These pastoral systems probably existed in a long-term equilibrium with the resource base, characterized more by resilience than stability. Grazing and burning led to an herbaceous and woody vegetation that would reproduce under those influences and which now may be at something less than maximum productivity.

Despite the pastoral strategies, large and violent fluctuations in both livestock and human populations probably occurred around long term averages. As a livelihood, pastoralism was attractive because of the high return per unit labor and per unit capital, but was risky because of the dependence of output on environmental factors. Surpluses generated in the form of male animals in excess to reproductive needs increased in value over a number of years but were continually susceptible to loss by disease and starvation. In traditional pastoral societies, investment in slower growing but more secure enterprises was not possible given the mobility of the pastoralist. This inability to insure that the surplus is available and usable when it is needed renders pastoralism vulnerable to disaster.

Sales of surplus animals are certainly effected optimally. It is less clear that herders commercialize all their surplus animals. It may be that those who do so are near the limits of their technology and would not do so if conditions were better. It seems unjustified to assert that this behavior is irrational from an economic standpoint. While it appears that grazing may have led to a reduction in the value of the range as a resource, increased commercialization of excess males will reduce stocking rates by only 1-5%.

It seems clear that pastoralism's traditional values provided the cultural base for long term survival. It is often assumed that these traditional values hinder the acceptance of new and "better" strategies;

yet, it is equally likely that these values assure long term survival while the "better" strategies provide only short term financial gain.

Bedoian (1978) reported what appears to be the only attempt to quantify the shadow costs of traditional values. His study concentrated on formerly nomadic people of the Tunisian pre-Sahara who had left their traditional herding economy to sedentarize and who currently practice a mixed agro-pastoral economy. The study showed that the people worked harder in their mixed economy for their subsistence food intake than they would had to have worked in a hypothetical commercial economy. The author concluded that the current mixed economy was an optimization of economic and social values, in an area where the traditional economy had long since been precluded by land constraints. Human caloric intake could have been optimized with respect to labor by the adoption of a commercial economy, but the commercial economy precluded certain social values, or, put another way, may have had hidden costs that threatened the coherence of the family unit.

One can postulate a similar situation in the Sahel, wherein the traditional pastoral economy, always attempting to balance current consumption against risk aversion, has now been constrained to produce a cash output from a deteriorating resource base. This compromise becomes increasingly difficult to accomplish for poor herders, while wealthier herders may still be able to produce subsistence and cash with some satisfication of traditional values. Thus, development efforts must be considered from the perspective of the pastoralists as they attempt to effect these tradeoffs of current consumption and future security.

4.0 DIMENSIONS OF CHANGE

If the traditional pastoral systems as previously described worked fairly well in sustaining human populations, there is, in the recent literature, a recurring sense of something having gone wrong. In general, two types of negative effects are thought to have occurred. First is the oft-mentioned problem of resource degradation. In this case it is supposed that stocking densities rose sufficiently to threaten the productivity in some parts of the Sahel. A corollary of this degradation is that higher stocking rates previous to the drought increased the losses during the drought. A second effect and one much more difficult to define and measure is the increase in the vulnerability of the socio-economic systems in the Sahel. As described in Section 3, the pastoral systems in the Sahel allowed for a flow of animals and labor such that the risk for any one household was reduced. An increase in the vulnerability of these systems can be seen in the pauperization of less wealthy members of the society, a reduction in their certainty of subsistence and finally their permanent elimination from the pastoral society.

This section examines the major dimensions of change affecting pastoral societies. The term "dimensions of change" suggests that the intensity of these processes has been quite variable within the Sahel and therefore, will be of varying importance in any one region.

4.1 Population Growth of Animals and People

Many authors have suggested that demographic and herd growth, released by better medical and veterinary care, are significant destabilizing influences (Hoben, 1979; Ketalaars, 1978; Pratt, 1978; Gallais, 1977). It is clear that an increase in the number of animals past a certain point can lead to some form of range deterioration.

The relative rates of increase between human and animal populations are critical to interpreting the increases. The human population clearly depends on the animal population. A human population growth rate greater than that of ther herds would lead to greater exploitation of the herds for immediate subsistence needs. Pratt (1978) suggests that overgrazing is not so much the result of an unnecessary accumulation of animals, but rather of too many people attempting to maintain a viable subsistence herd. Ketalaars (1978) states that in Mali, real herd growth closely parallels that of the population. On the other hand, Gallais (1977) states that between the 1914-16 drought and that of 1969-1973 the human population increased 2 to 3 fold while the herd increased 4 to 5 fold. Though perhaps these differences reflect different scales of inquiry in a subject with great regional variation, it is not clear if the herds have trailed, matched or exceeded the human population.

While an increase in herd size may establish a feedback loop leading to environmental degradation there is some reason to believe that negative effects on animal performance, especially on milk production, may occur before the vegetation is affected. Two older men, a farmer and a Foulbe herder interviewed in Niger by Laya (1975), both mentioned that people owned more cattle now but derived less milk from them, with the perceived cause being a lack of pasture. Yet, according to Rippstein and Peyre de Fabregues (1972), this same area of Niger was not grazed to its full potential. Thus, poor animal response, not reduction in primary production, is the first indicator of overgrazing.

4.2 External Domination and Administration

Colonization and the establishment of a central administration has had a multitude of effects on pastoral societies. A critical effect for some societies, especially the Twareg and the Moor, was the elimination of slavery (Bernus, 1977a, 1977b; Horowitz, 1977). The loss of this critical labor supply led to a shift from labor intensive sheep herding to less demanding cattle herding. The traditional barter of protection for grain was also eliminated. The loss of grain supplies forced the Twareg toward commercial means of obtaining grain, while the emancipated slaves competed with their former masters for pasture. Among the Moors, the lack of sufficient herders prevented their emigration from Mauritania during the drought (Bellot and Bellot-Couderc, 1979).

The subjugation of the traditional powers by the colonial forces meant an increase in security, greater freedom of movement, and the elimination of the traditional systems of territorial organization. The colonial peace allowed the use of previously little used areas, but also encouraged the northward movement of agriculturists and Sudanian cattle herders,principally Fulani, into formerly Twareg controlled lands (Eddy, 1979; Swift, 1977a, 1977b; Bernus, 1975). While the Fulani were originally obliged to pay tribute to the Twareg, they later dug wells of their own, circumventing the weakened traditional power structure and competing directly with the Twareg for range resources. The creation of state owned wells hastened this process (Swift, 1979). The nullification of the dina code for the Niger delta by the Malian government led to similar chaotic exploitation (Tubiana, 1975).

The destruction of traditional social control of resources and its supposed replacement by national codes has likely fostered a more exploitative view among herders and farmers. Thomson (1977) concluded from a study of forestry policy in Niger that the exclusion of villages from policy formation dissolved any sense of responsibility that villagers had towards local resources, causing both exploitative use of the resources by the villagers and manipulation of the law for personal gain by government officials. The imposition of national codes created paradoxically what they were designed to prevent. Finally, in most Sahelian countries, the government elites have been drawn mainly from the former tributary groups of the pastoralists with the creation of a political climate generally unfavorable to pastoral interests (Horowitz, 1977, 1978).

4.3 Provision of New Water Points

The creation of new dry season pasture from former wet season pasture by the installation of deep wells has been a major effort by most Sahelian governments (Bernus, 1975; Diallo, 1968). While the goal of reducing the dry season constraints on livestock performance was reasonable, the lack of regulations governing the use of the wells led to both a very rapid depletion of forage during the dry season and a decrease in the number of woody species within 3-4 km of the well, thus negating the original value of the well (Rippstein and Peyre de Fabregues, 1972).

Ironically, the legislative texts authorizing the installation of wells in the pastoral zone of Niger provided for the attribution of each well to particular pastoral groups, the interdiction of wet season grazing within 20 km of the well and the annual determination of carrying capacity (Bernus, 1977a). Yet the administration found it impossible to give water to some herders and to refuse it to others. Consequently, stocking rates at all the wells studied by Peyre de Fabregues (1971) were 2 to 4 times the calculated carrying capacity of the adjacent range. As with the forest example previously cited, the abrogration of traditional rights made exploitative practices rational, yet led to a globally poorer situation.

While the wells reduced an important labor constraint on herd management, the deterioration of the forage situation certainly did not escape the preception of the herders. Monod (1975) cited a survey made by the Service de l'Animation (Niger) which found that herders preferred open cement wells and hand watering to pumped boreholes because of the risk of overstocking and weight loss by the animals during the dry season.

4.4 Loss of Land to Agriculture

While the installation of water points expanded the resource base for pastoralism by converting wet to dry season pasture, the expansion of agriculture into former dry season pasture has led to a net reduction in the pastoral resource base (Van Raay, 1975; Hoben, 1979; Ketalaars, 1978). Twenty years of relatively good rains that preceded the drought encouraged an expansion of millet cultivation northward into dry season pasture. Herders returning to those lands during the drought years found them largely occupied. Bellot and Bellot-Couderc (1979) explained this expansion as the result not only of population growth, but also of increasing financial demands on farmers, leading to the displacement of the lower value food crops to the north by the higher value cash crops.

The expansion of agriculture into the flood recessional ranges has had particularly severe effects (Swift, 1979; Sabry, 1972; Ketalaars, 1978; Van Raay, 1975). While the conversion of this land to agriculture renders the adjoining wet season range much less valuable, the returns to agriculture may make the conversion a Pareto optimum with all the attendant problems of compensation.

The fear of the loss of rights to land may be an important motivation for pastoralists. Fumagalli (1978) stated that among the Masai in Kenya the fear of losing their landrights upon independence as well as the losses during the 1959-61 drought prompted the tribe to introduce innovations in their traditional system of husbandry, paving the way for the group ranches scheme.

4.5 Sedentarisation

While mobility is a crucial element in the traditional pastoral strategy, it makes pastoralism a less comfortable lifestyle. While pastoralism can give a high return to labor, the restrictions placed on consumption by mobility and the high risk associated with environmental variation make its global advantage over agriculture problematic. As Horowitz (1972) pointed out, cultural values, rather than economics, provide the rationale used by both herder and farmer to justify their type of livelihood. Thus it is not surprising to find that a reduction in mobility and sedentarisation has been an important dimension of change in the Sahel.

As noted in Section 3.0, sedentarisation, at least temporary, has been an integral part of pastoral contingency strategies. However, the literature shows an increasing rate of permanent sedentarisation, particularly among the Fulani. Van Raay (1975) suggested that the increased contact between pastoral and non-pastoral peoples, and the shift in political power during the Fulani jihad of the 1800's in northern Nigeria made agriculture an attractive and possible alternative to pastoralism, especially for the poorer households. Stenning (1959) showed how colonial policy of the early 1900's favored the establishment of Fulani villages in northeast Nigeria. This historical process in Nigeria has progressed to such an extent that both Van Raay (1975) and Fricke (1975) present typologies of cattle owners based on the mixture of cropping and herding. While the relatively wetter areas of the Sudan clearly permit effective cropping, sedentarisation among Sahelian people also occurred, especially around wells, and was accelerated by the drought (Swift, 1977a; Bellot, 1979).

The advantages of sedentarisation for the pastoral economy include better relations with local farmers, year-round access to markets and increased and more certain access to dry season forage, especially crop residues (Hickey, 1978; Van Raay, 1975).

The dangers of sedentarisation for pastoralists include possible resource degradation in the long run and increased vulnerability of the herds in the short run. Clanet (1977) found that in Chad the Arab Mahaboub who had not maintained their transhumance suffered much higher losses of livestock during the drought than the neighboring Kreda who had. Indicative of these tradeoffs, Fumagalli (1978) noted that the Poka in East Africa stayed within their group ranches, even when better fodder was temporarily available elsewhere, because other inputs, such as cattle dips and water development, rendered their operations more beneficial in the long run.

4.6 New Livestock Owners

Given the high rate of return on capital that livestock give in the West African economy, one might expect that those with capital would invest it in livestock. Such investment has clearly occurred in West Africa, with salaried employees and traders buying animals and often hiring pastoralists to herd them (Frantz, 1975; Van Raay, 1975; Swift, 1979). Investment in cattle, of course, does not increase herd size but rather may change the distribution and management of existing animals.

The importance of these transfers is not clearly known. A certain amount of distrust between the farmer/herd owner and the salaried herder may lead to a reduction in the transhumant movements formerly followed by the herd, with consequent increases in grazing pressure. Furthermore, the increased value of local forage resources may lead village herd owners to deny pastoralists access to these resources, especially crop residues (Sabry, 1972; Van Raay, 1975). Since the herds are generally for eventual resale and have higher percentages of males (Swift, 1979) the important environmental feedback mechanism of milk production is much less important in the eyes of the herd owner although it may still concern the salaried herder. This non-subsistence goal of investment may thus lead to reduced monitoring of animal performance and greater risk of overgrazing.

A third important feature of investment in cattle is the spread of the idea that social status is directly related to the number of cattle owned (Frantz, 1975). It is ironic that this idea, so often attributed to traditional pastoralism, may actually be a result and not a cause of recent change.

4.7 Monetarization of the Pastoral Economy

The conversion of a subsistence pastoral economy to an increasingly commercial economy is probably the most important and far-reaching change affecting pastoral societies (Sabry, 1972).

Money became a necessity when the colonial administration demanded cash payment of taxes (Horowitz, 1977; Kates et al., 1979). The colonial peace and the beginnings of a modern infrastructure promoted the development of a reciprocal trade in animals and consumer goods. The economic development of coastal regions led to a steady increase in demand (Ketalaars, 1978; Horowitz, 1977). Such an apparently favorable situation has led to several unforeseen results.

The increase in the supply of animals did not arise from an increase in the productivity of the herds but rather from a greater rate of offtake. Reviewing the Sahelian livestock economy, Ketalaars (1978) noted that the

3.5% annual increase in supply was matched by a decrease in animal weight as continually younger animals were sold on the market. Ketalaars interpreted these sales of younger animals as being required by increased financial demands made on pastoralists. Indeed, Delgado (1979) indicated that there was a definite financial advantage to earlier sales. The increased sales may have reflected a greater reliance on the market for the provision of food, the additional financial burden of taxes and consumer goods, and a reduction in the level of risk aversion.

The increasing demand, especially for beef, encouraged many pastoralists to change their herd composition from camels and goats toward sheep and cattle (Swift, 1977a). This conversion may have been hastened in some areas by the liberation of slaves. While sheep and cattle are more valuable market animals, they are not particularly suited to the arboreal dry season systems of the Sahel. They are considerably more vulnerable to starvation during drought than are goats or camels as the last drought clearly shows (Gallais, 1977).

The shift in herd composition toward less resistant animals exacerbates the market glut that normally accompanies a drought. Thus, the pastoral surplus generated by these herds is relatively less valuable in a disaster (Swift, 1979). Thus, a higher offtake and the devalorization of the pastoral surplus may cause a serious increase in vulnerability.

A very important consequence of monetarization has been the destruction of social cohesion with the rise of social stratification and an increase in disparities of wealth. Two factors contribute to this process: increased access to alternative employment and reduced numbers of animals available for redistribution through traditional channels.

Within the traditional system, the maintenance of wealth required labor, and the benefits of the stock redistribution system were evident. With the rise of a cash economy in which labor and animals were sold, herds could be amassed rather quickly without incurring any social obligations. Thus, those members of a pastoral group who left the traditional system, returned with cash and invested in animals accumulated large numbers of animals that were no longer available to poorer households (Hjort, 1976a; Dahl and Hjort, 1976).

On the supply side of this transfer, those who had excess females found in the market a lucrative alternative to the traditional redistribution systems (Swift, 1977b). While this decision implied a sacrifice of long term security in the form of social obligations, it was an appropriate means of satisfying rising consumer desires. With a reduction in the number of subsistence animals available to them, poorer households had little choice but to exploit their herds at an ever increasing rate, eventually selling fertile cows, the capital of the pastoral economy (Swift, 1977a).

Once the transfer of capital in the form of cows and other animals began, so did the process of social and economic stratification, with the rich getting richer and the marginal getting either more marginal or eliminated from the pastoral economy (Sabry, 1972). Management of animals for commercial and status reasons, never possible under the traditional system, became attainable for some individuals (Hjort, 1976a). A reduced concern for milk production and tension between owner and employee may have reduced mobility and increased overgrazing. With the concentration of wealth came concentration of power and increased possibilities for exploitation (Sabry, 1972; Hjort, 1976b). The pauperization of marginal households led to increased out-migration (Sabry, 1972).

While little data exist to support these contentions, Van Raay (1975) states that class formation has already begun in rural Nigeria.

5.0 THE NEGATIVE EFFECTS OF CHANGE

While undoubtedly the changes of the last hundred years have had both positive and negative effects, it is not obvious that pastoralists are better off now than they were under the traditional system. An examination of the negative effects of change may allow development planners to design projects that will truly improve pastoral welfare.

Negative effects manifest themselves in two ways. First, the animal population can grossly exceed the carrying capacity of the range, leading to range degradation. Secondly, the animal population can drop below the level needed for subsistence, leading to pauperization, reversion to other livelihoods and starvation.

5.1 Resource Degradation

An examination of the accounts of early travelers and historians as well as of more recent studies provides evidence of desertification, the most extreme form of degradation. Depierre and Gillet (1971) present convincing evidence of desertification in Chad, documenting the disappearance of rivers and other water sources, the southward migration of large mammals, and the removal of forests. While Depierre and Gillet advance several causes, their first, that of long-term climatic change, is refuted by Bille (1974) who states that the first observations of the Sahel were made during the peak of a very wet period and cannot be considered as representing the average condition. Depierre and Gillet also argue that man has contributed to desertification, either directly through the removal of trees and the use of fire, or indirectly through overgrazing and trampling by livestock. The relative contribution of agriculture and grazing to desertification will be discussed below, but their common result (a loss of cover with concomitant increase in albedo) may enhance aridity if the atmospheric models discussed by Hare (1977) are accurate.

The expansion of agriculture is probably more to blame for the removal of vegetation and the increase in soil erosion than grazing (Hoben, 1979). In one of the few attempts to quantify the progress of desertification, Gaston and Dulieu (1976) compared aerial photographs of the Kanem (Chad) taken in 1974 with those taken in 1964. They found the greatest losses of tree cover and increases in soil erosion were due to the total absence of precipitation for several years in some areas and the expansion of millet cultivation in others.

Where overgrazing has occurred, such as near wells and villages, it has manifested itself via the mechanisms discussed in Section 2.0: local trampling, changes in herbaceous composition and the removal of trees. Under the traditional regime, a great disaster like the drought of the 1970's would have relieved the pressure on the range, allowing for a temporarily positive trend. However, according to Gallais (1977), the number of animals surviving the recent drought was great enough to insure that grazing pressure would continue unabated. Certainly a major factor contributing to the resilience of the herbaceous layer, and thereby the maintenance of the herds, is the generally sandy soil of the Sahel. While Bernus (1977a) and Dulieu _et al_. (1977)note an increase in soil crusts, their formation has been confined largely to heavier soils and the most abused of areas. Sandy Sahelian soils, while perhaps nutrient poor, remain permeable after denudation and permit regrowth of the herbaceous stratum.

Thus, the evaluation of resource degradation requires that one look past the cycle of denudation and rainy season regrowth. While the threat of true desertification (a complete lack of cover accompanied by the formation of impermeable soil crusts) has probably been overestimated (Hoben, 1979), the reduction in the value of the range via the losses of dry season arboreal forage with a reduction of soil organic matter and overall production, is probably very significant in many areas.

5.2 Loss of Household Viability

The loss of household viability results from an imbalance between the human and animal populations (Swift, 1977b). Several possible configurations of the man:animal relationship are shown in Figure 2.

The representations shown in Figure 2 are abstractions of reality and cannot convey perfectly the present situation. Since they are used here as means of generating alternative approaches to development, it is important to note their shortcomings. First, the figures do not represent energy flows and should not be confused with trophic pyramids. The relative length of the lines shows the degree of environmental feedback, such that a line equal to or longer than that of the supporting resource base signals a deterioration of that resource base and initiation of negative feedback. Since this representation is used in Figure 3 to outline a historical process, the carrying capacity is not an annual value, but rather a long term value that includes occasional overstocking and variable rainfall. It is the level of stocking for a multi-year period which if exceeded will result in a net negative range trend, given the pattern of primary production during that period and the existing pastoral management. Thus, its value varies according to the environmental conditions during that period and can only be determined exactly *a posteriori*.

Second, the relationship between the human and animal population

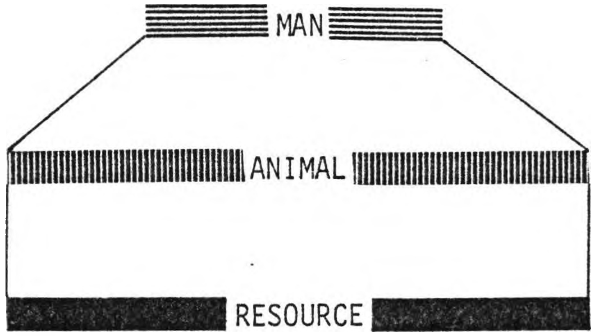

Figure 2a. Range degradation and excess animals

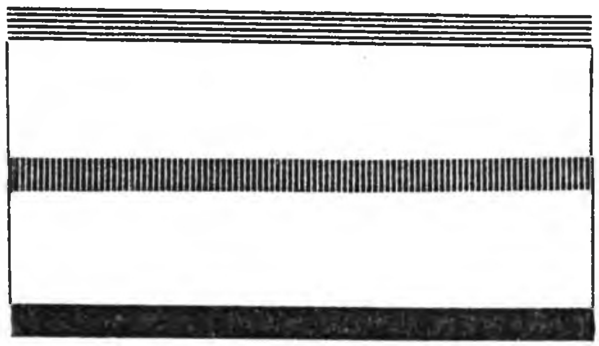

Figure 2b. Range degradation and insufficient animals

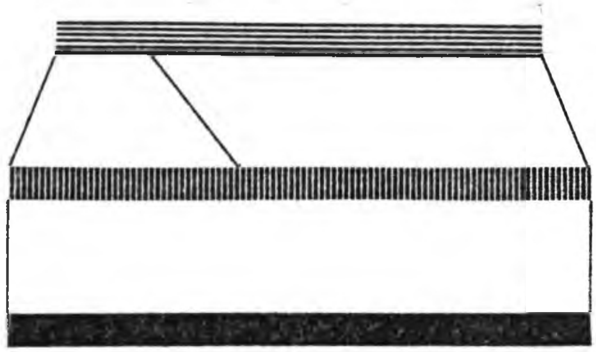

Figure 2c. Range degradation and unequal distribution of animals (excess animals for wealthy owners, insufficient animals for poor owners).

Figure 2. Possible Configurations of the Man:Animal:Resource System in the Sahel

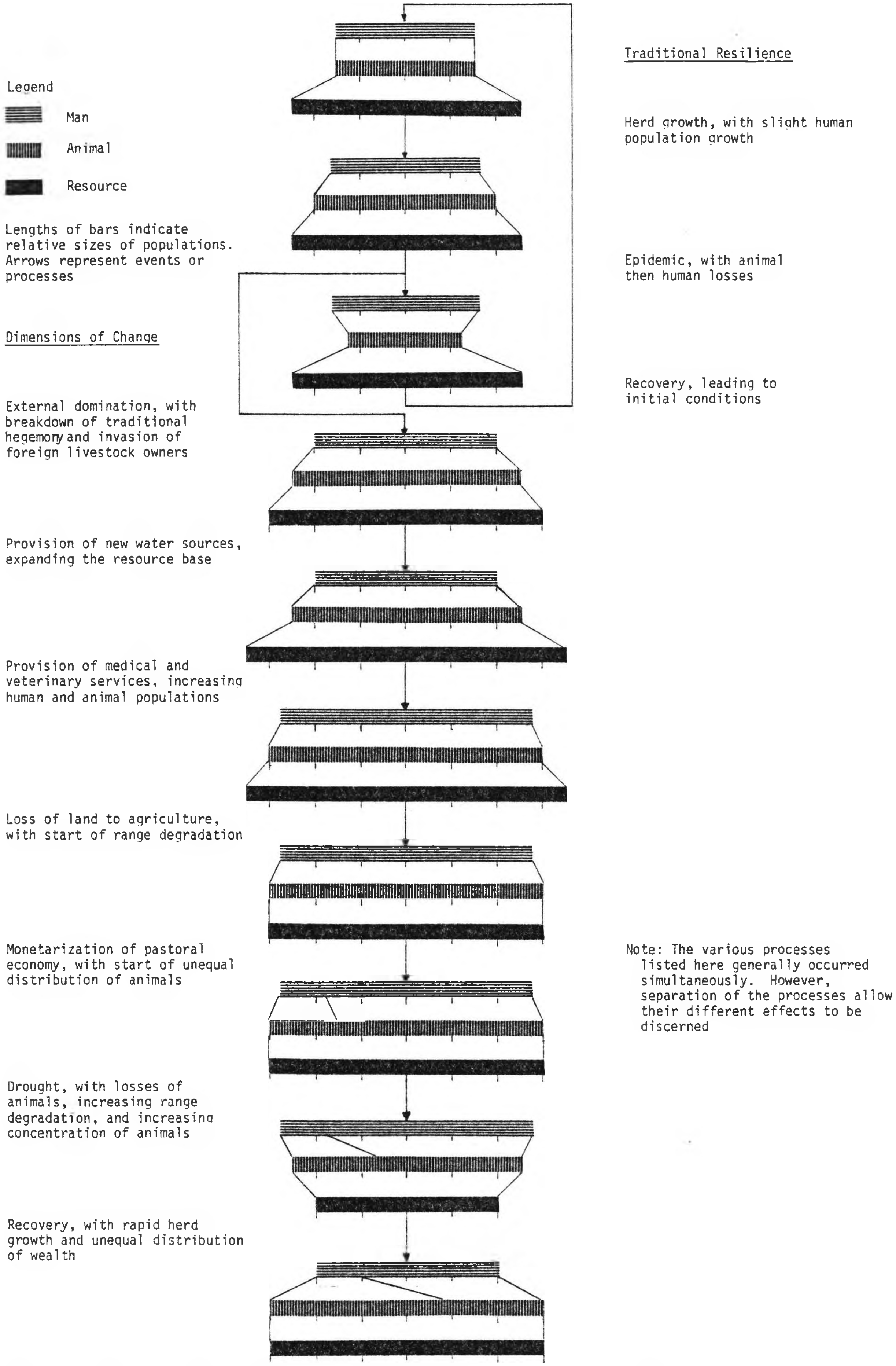

Figure 3. Hypothesized Historical Development of Man:Animal:Resource System in the Sahel

is defined by a given pastoral technology and output. As such, pastoral contingency strategies, especially agriculture with its costs and benefits, are not included in the figures. Inclusion of these strategies would change both the human carrying capacity of the environment and the minimum number of animals needed to support a family.

Lastly, representations based on population size can only show that population control is the final answer. While this contention is true and must be considered in the long run, full use of existing resources via technological and social innovation is the main concern of this paper.

The present relationship of the human and animal population and the distribution of animals within the human population are not clear in the literature. Several possible configurations are shown in Figure 2, a-c.

Figure 2a portrays a human population holding more animals than it needs to meet its subsistence needs over a multi-year period with the animal population so large that it initiates range degradation. This configuration shows no loss of household viability. Development policies based on this "hoarding of excess animals" perception would reduce range degradation by increasing offtake and re-educating the pastoralists. This perception appears to have been the dominant one among development planners, yet it is incorrect since, as Shapiro (1979) and Ketalaars (1978) show, there are not large numbers of excess animals in Sahelian herds.

Figure 2b shows an animal population large enough to degrade the range but not large enough to support adequately the human population. The figure should include pastoral contingency strategies. However, these strategies may cause even greater resource degradation.

Development policies based on this perception would aim at increasing the returns to other environmentally-sound activities, thereby encouraging people to leave pastoralism. Policies could also aim at enlarging the resource base. Finally, policies might aim at changing the exploitation of the animal population such that the animals would support a greater number of people. Ecologically, such a technological change implies harvesting the herd so that more of the primary producers' energy is converted to animal products and less is dissipated as maintenance. Economically, it means slaughtering or selling more animals. While some additional males could be sold, any large change in ecological efficiency involves the sale of females, an action that contradicts a major risk aversion strategy.

An increase in ecological efficiency can be achieved only by a change of the pastoral environment such that the risk of loss of breeding stock is reduced (Van Raay, 1975). Improved nutrition and reduced calf mortality could make greater offtake a viable survival strategy, provided that the price relationship of meat to grain remained unchanged.

Figure 2c shows a yet more complicated configuration in which the animal population is large enough to both degrade the range and support the human population. However, the wealthier portion of the population owns proportionally more of the animals such that the mass of the cattle owners find themselves with less than the minimum level of animals. Poorer herders might find their access to range resources restricted if, as Swift (1977b) found, the wealthier owners expropriated the range by private water development. A sketch of the historical antecedents of this situation is shown in Figure 3. In the author's opinion, this configuration is the best approximation of the current state of Sahelian pastoralism.

On one hand, one could consider this concentration of wealth as the formation of investable capital or as the efficient allocation of resources by the market. On the other hand, one could see the destitution of the poorer pastoralists and farmers as a result of exploitation by the richer classes. The perception that is "correct" and therefore the basis of development policy depends on the dogma of the national elite. Technical interventions can only be tools to achieve those configurations of man, animal and land that national leaders see as politically desirable and attainable. A redistribution of wealth without a replacement for the traditional system that maintained household viability through labor and animal flows would inevitably lead to a similar situation. Policies with no concern for population growth, alternative livelihoods or resource improvements would lead to overpopulation and desertification.

No quick and easy answers evolve from this last configuration, a sign that perhaps as a description it is correct. Its use for prescription depends on national policy. Development planners who operate within this policy should use this description as a framework within which to analyze the probable effects of development projects.

6.0 COMPONENTS OF PASTORAL DEVELOPMENT

All development programs must have a goal, even if that goal is difficult to define. The following discussion assumes that the goal of pastoral development is the improvement of pastoralists' welfare. This obvious goal needs restatement, since as Hoben (1979) points out, past project activities seem to imply that urban meat consumers or even the animal population itself are the target populations of projects. Currently, some authors recommend the development of a perceived ecological complementarity of the Sahel and the Sudan as a rational global scheme for the development of the livestock economy (Le Houerou, 1980). Yet it is not at all clear that this "stratification" of livestock production is in the interests of the pastoralists (Horowitz, 1977) or even economically rational (Bellot and Bellot-Couderc, 1979).

The analysis of Section 5 gives several ways of increasing pastoral welfare. Reducing the financial load in the form of taxes would certainly increase the welfare of the remaining pastoralists. Pastoralists currently see only one quarter of their taxes returned to their regions in the form of investments (Gallais, 1977). While tax reform is an interesting possibility, it is unlikely that taxes will be reduced.

Lacking a reduction in the demand placed upon the herd by the household, an increase in herd productivity is the major means of increasing pastoral welfare. Increasing herd productivity has several interrelated components. The first is improved herd nutrition which, aside from mineral supplements, requires a higher and more even production of forage. A second component is better veterinary care, leading to reduced animal mortality and better reproductive performance.

As many authors have pointed out, however, traditional risk aversion strategies render these two approaches mutually exclusive. Gains in animal health inevitably translate into increased grazing pressure. Even if it were possible to increase forage production to the extent that poor pastoralists had sufficient subsistence holdings, animal populations would continue to increase, negating the forage increase. Another drought with its sudden fall in forage production, consequent overstocking and massive sales would return the populations to their current dilemma.

Clearly an increase in primary production will require not only an initial destocking but also a system to control animal numbers even if those numbers exceed the current stocking level. Control of numbers will be rational only 1) when each household maintains a sufficiently productive herd in "normal times" and 2) when a savings-insurance system exists to guarantee that the household can survive a disaster as a stock breeding unit. Both of these functions were previously performed by the lineage system of the pastoralists and were undone by external domination and commercialization. Thus, if pastoral development projects cannot themselves undo the processes of population growth and commercialization, they can seek to create social institutions that will restore some of the territorial organization and insurance protection afforded by the traditional society.

These three components, increased primary production, improved animal health and savings-insurance systems-are not independent. While they are discussed separately below, it should be remembered that they must be implemented together.

6.1 Improving Primary Production

Since the total primary production is the product of area and productivity, an increase in total production will follow from an increase in either of those factors.

6.1.1 Increasing Range Areas

Although the enhancement of employment and investment opportunities in other sectors does not increase exploitable range areas, it leads to the same result by reducing the pastoral population (Wagner, 1978; Baker, 1973). This process has been an on-going one, especially in more rapidly developing economies (Johnson, 1975). It should be realized that reinvestment of agricultural surpluses in livestock may have detrimental environmental effects, while reinvestment of commercial earnings may exacerbate the unequal distribution of wealth.

According to the analysis of Section 3.3, dry season forage is the factor limiting animal performance. Thus, pastoral development projects could attempt to open new dry season pastures. While some analysts might categorize this approach as one that sidesteps the "real" problem of resource management, it can certainly be justified as bringing into production more of the resources possessed by a nation. In terms of economic optimization, the expansion of the resource base may have a more favorable benefit: cost ratio and should be pursued until that ratio drops to that expected from resource management.

The installation of new dry season water points is an important means of enlarging the resource base and one that has been attempted by all Sahelian states (Diallo, 1968; Bernus, 1975) largely because of its appeal to the pastoralists, government officials and donor agencies (Hoben, 1979). However, some changes in the conception and implementation of water development will be necessary if past mistakes of overstocking and degradation are to be avoided.

Attribution of wells to specific pastoral groups is necessary to encourage rational range use. Since access to traditional wells required inputs of labor and payments, the construction of new wells might be implemented in a similar fashion. Government technical services would build an improved well only after a contract with a specific group of pastoralists had been arranged. The terms of the contract would require some input of capital or labor by the pastoralists themselves. De facto grazing rights to the adjacent lands would thus belong to that pastoral group (Bernus, 1975).

Defining suitable pastoral groups will probably present difficulties. Where coherent lineage groups still exist, they could form the basis for water development. Where a lineage group includes both wealthy and poor herders, or where several different groups compete for the use of the range, questions of correct apportionment and social justice become paramount. If suitable social groups do not exist, one is confronted with demonstrating to herders the value of organizing to gain permanent access to water, a problem of perception addressed more directly in Section 6.2.3.

If appropriate pastoral groups can be defined, it is likely that they will have little or no investable surplus (i.e. surplus animals). Only wealthy owners can currently invest in water development, and in Somalia, they do so without any matching government funds (Swift, 1977b). Projects aimed at helping poorer pastoralist must therefore advance credit to suitably constituted groups for investment in wells. It is imperative that repayment of these loans, though on easy terms, be enforced so that the borrowers perceive the loan as a real investment on their part. The temptation of government and donor agency officials to forego the repayment requirement in order to show greater physical achievement (Hoben, 1979) could easily undercut the goal of attributing wells to pastoral groups.

If one assumes that wells can be attributed to particular pastoral groups, that attribution will not in itself necessarily prevent overstocking. As Fumagalli (1978) noted in east Africa, pastoralists on group ranches opened their ranches to all comers, thereby assuring their access to other lands in the advent of drought on their own. The problem of risk which this behavior attempts to reduce, exists on a geographic scale greater than that of any single well.

The opening of a new well will increase the resource base, the major concern in this section. The attribution to a group of people will increase their property rights which may be traded to others as a form of risk aversion. Thus, such water development serves two important functions, but does not directly attack risk, the root of overstocking. The most efficient use of water development will occur in a program that deals more directly with risk.

6.1.2 Increasing Range Productivity

Three general approaches for increasing range productivity in the Sahel have been advanced: the institution of a grazing system, the rehabilitation of degraded lands, and the planting of forage crops.

6.1.2.1 Grazing Systems

The guidelines given in the literature for an ecologically sound grazing system are designed to improve the performance of the traditional pastoral technologies by changing the level of the current limiting factor: dry season forage, usually in the forms of shrubs and trees. The following guidelines are drawn from Peyre de Fabregues (1971), Rippstein and Peyre de Fabregues (1972), Novikoff (1976),Van Raay (1975) and Granier (1974).

1. The seasonal transhumance of traditional pastoralism should be maintained.

2. A clear distinction between wet and dry season range should be encouraged. Wet season ranges are those near temporary water points, with large percentages of plants palatable only during the wet season and without large percentages of shrubs and trees.

3. Maximum dispersion of herds on the wet season pasture and more complete use of these pastures should be encouraged via the development of temporary water points. While such water development should be carefully related to the surrounding vegetation, it serves the additional function of delaying the return of the herds to the dry season range.

4. Dry season range (i.e. that range with sufficient shrub and tree populations near permanent water) should be protected during the wet season (a corollary of the maintenance of transhumance).

5. Carrying capacities must be calculated and observed on dry season range. Observing carrying capacities is necessary first to insure better animal nutrition for the duration of the dry season and second, to avoid range degradation.

6. Dry season range should be located so that the animals can be removed before the plants mobilize their reserves. Generally this criterion places dry season pastures geographically between early wet season and full wet season ranges.

7. If the expansion of dry season range proceeds to such an extent that wet season pastures begin to suffer from overstocking, a wet season rotational system might be useful. However, grazing trials in California do not support this contention in Mediterranean annual grasslands (Pitt and Heady, 1979; Heady, 1961). While long term grazing trials are required to determine if a rotational system would improve overall efficiency, it seems likely that the equivalence of wet and dry season ranges as limiting factors would signal the need for a more intensive forage culture.

An attractive aspect of this grazing system is that it is centered on control of dry season pasture only. Given the traditional attachment of pastoral groups to particular wells and water sources, the definition of coherent socio-ecological units may be much less difficult than commonly imagined.

Several questions can be posed as to the benefit:cost ratio and the feasibility of this grazing system. The main value of this grazing system lies in its ability to reduce the dry season forage constraint. As shown in Section 2, trees and shrubs respond well to protection. Granier (1974) proposes that this grazing system would increase the carrying capacity of the land by 50%, but little data exists to indicate the grazing pressure that a renewed arboreal range could withstand. An excellent opportunity for demonstrating and quantifying the benefits of the grazing system lies in coupling the implementation of the system to the water point development alternative previously discussed. This coupling of grazing systems with water development within the as yet undefined framework of an insurance system would produce synergistic effects.

A second technical question involves the determination of carrying capacity in a highly variable environment. In an excellent review of pastoral development projects, Hoben (1979) paraphrases the position of Sanford regarding what Sanford terms opportunistic versus conservative strategies. Briefly, Sanford argues that the conservative strategy of range management fixes a very low but constant carrying capacity in order to allow for periodic drought. Traditional strategies, which are opportunistic, allow the animal population to closely follow the primary production, thereby leading to more efficient utilization. Sanford suggests that development projects should increase the efficiency of this opportunistic strategy, not by intervening in production, but rather by facilitating destocking in times of disaster.

While Sanford's argument has much to recommend, it errs in its assessment of the value of range management. As a science, range management does allow variable annual carrying capacities that maximize utilization while minimizing degradation. As shown in Section 2.2.1, primary production and consequently the annual carrying capacity fluctuates greatly in the Sahel. If dry season grazing is a constant influence, it may in one year affect the level of reserves in perennial plants. Yet the importance of this loss of fitness can only be evaluated in the light of the following year's rainfall. Heavy grazing in one year may be compensated by heavy rainfall the next.

In a stochastic environment, any exact definition of carrying capacity for dry season range must consider this interaction of the known current year's production with stocking levels in the light of the probable rainfall for the next one or two years. Carrying capacity,so defined, is a function, yielding a single carrying capacity value for a specific level of risk of damage to the vegetation. For example, with a given year's production, a stocking rate of 11 ha hd^{-1} may correspond to a 10% chance of a loss of primary productivity attributable to grazing in the following year, while a rate of 9 ha hd^{-1} may correspond to a 20% chance of loss. The paucity of grazing trial data in the literature precludes a determination at present, but experiments can be designed to provide the data. Once derived, carrying capacity functions could be used within a grazing system to generate flexible annual carrying capacities that would allow efficient use of the primary production without unduly endangering the vegetation.

A problem does arise in a moderate to severe drought when the probability of significant damage to the vegetation approaches certainty. The need to destock in an optimal fashion (i.e. before both the grazing and price system collapse) is imperative. A major problem in destocking is the market glut and the consequent devalorization of the pastoral surplus. A grazing system that provides additional dry season forage and better animal performance would reduce the need for large herds (Van Raay, 1975). Thus, in a drought, fewer animals would need to be removed, or could be removed at a slower pace, reducing the glut.

If increased productivity and lower variability are the benefits of this grazing system, its costs include a reduction in the pastoralist's flexibility and freedom, the maintenance cost of the social institution required to enforce grazing controls on dry season pasture, and, rightly or wrongly, the perceived opportunity cost of selling animals rather than holding them. While it might be possible for an economist to perform a benefit:cost analysis, the truly critical analysis will be that performed by the pastoralists themselves. Realistic pilot grazing systems must be established in order to aid pastoralists (and technical experts) in evaluating the worth of these systems (Section 6.3).

6.1.2.2 Rehabilitation of Degraded Lands

Tillage of degraded sites, with or without reseeding, has shown impressive results in the Sahel (Boudet, 1976; Penning de Vries, 1978). While the very fact of degradation shows that these sites require more careful management than sandy sites, rehabilitation could expand the resource base. Their often lower topographic position makes them valuable for dry season forage production.

While the costs of rehabilitation make it of dubious value in a transhumant system, it could be an important improvement for village-based livestock owners. It seems likely that the investment of labor by an individual or groups of farmers in the rehabilitation of an area of land will confer exclusive use of that site to them and that fences constructed by them would be respected. In this context, land rehabilitation should be considered as another agricultural alternative whose adoption by farmers is conditioned by the availability of labor and capital and the expected returns. It would seem most beneficial in this case to seed shrub species rather than grass in order to maximize dry season forage production.

6.1.2.3 Range Seeding

The oversowing of natural ranges with forage crops, especially legumes, has been suggested by several authors (De Wit, 1975; Rains, 1963, 1975;

Penning de Vries and Heemst,1975). They could increase dry season forage availability in several ways. First, some legumes are relatively unpalatable during the wet season, but cure well, providing nutritious standing fodder during the dry season. Second, grazing of a mixed grass-legume community could lead to increased availability of nitrogen and consequently, higher wet season productivity. Subsequent mowing of the community could provide a nutritious hay for the dry season (Valenza, 1970).

The use of forage crops is the most intensive of the three methods for increasing resource productivity. Since legumes are commonly outcompeted by grasses (De Wit, 1975), their maintenance in the community of a sown range will probably require manipulation of wet season grazing intensities and timing. While the benefits of improved early dry season forage, delayed use of dry season pastures, and increased cycling of nitrogen with higher productivity are potentially great, the costs are those associated with grazing controls in general.

As with rehabilitation, the adoption of this technique is most likely among sedentarized livestock owners who have more permanent access to land. An evaluation of the benefit:cost ratio of this intervention requires consideration of the increase in animal response expected from a sown range and the cost of labor during the cropping season. The introduction of an appropriate technology, such as animal-drawn mowers and rakes, could reduce the wet season labor constraint, but would require the provision of credit and a higher rate of commercialization.

If, in fact, any of these techniques do provide substantially higher production adequately spaced throughout the year, one might expect transhumant pastoralists to reduce their movements and sedentarize where possible. While sedentarisation may be an important goal of government officials for other reasons, it is important to note that it will occur voluntarily only when animal needs can be met within a reduced area (Van Raay, 1975).

6.2 Increasing Security

If the interventions discussed in the previous section increase dry season production and productivity, they would represent changes in the environment of pastoralism similar in magnitude to the introduction of human and animal health services early this century. However, while earlier changes pushed pastoralism toward individualism as a rational survival strategy, increased primary production can only be achieved via the institution of control of animal densities during at least part of the year.

Though historical mechanisms existed to control the ratio of man to land, recent evolution toward intensification of land use by grazing controls has not occurred. One could argue that this absence of evolution results from too little time having elapsed or from pastoralists remaining ignorant of ecologically sound land use. Yet other factors may intervene as well. As noted in Section 4, virtually all of the dimensions of change have increased the uncertainty of pastoralism. While ecological necessity or social structures precluded the monopolization of resources in traditional societies (Hoben, 1979), class formation with the unequal distribution of wealth in recent years makes over-exploitation of the resources, if only to obtain a reasonable subsistence holding, the only rational strategy for pastoralists.

If one assumes that primary production can be increased sufficiently to provide the basis for reasonable subsistence holdings, it is imperative that these increases accrue to poorer herders, if for no other reason than to reduce to whatever extent possible their drive for larger herds.

In addition, the inevitable re-occurence of a major disaster, the effects of which can be only partially mitigated by resource management, remains a strong justification for the traditional risk aversion strategies. While the potential for devalorization of livestock in times of disaster is well known, the lack of other investment opportunities perpetuates the position of livestock as the best investment for those with capital.

Thus, given the precarious position of pastoralists, the loss of security needed to attain and maintain the improved resource base may be greater than the security the resource base affords. In the absence of an attempt to deal with other sources of insecurity (recurring drought, no alternative form of savings, no certainty of a favorable allocation of resources) movement toward an improved resource base could very well be irrational on the part of poor herders.

6.2.1 Veterinary Care

There is no question that animal mortality could be reduced in Sahelian herds. In particular, losses of calves have a depressing effect on herd growth. The losses must be reduced if the efficiency of secondary production is to be maximized. Pastoralists do appear willing to pay for some veterinary services (Hoben, 1979). However, the costs of the annual immunization campaigns are currently borne by governments and donor agencies, so that the benefit:cost ratio of non-subsidized veterinary care is not clear. While pastoralists should get some services, veterinary or otherwise, for their taxes, it is important to determine the ecological and economic conditions under which veterinary treatment can pay for itself.

6.2.2 Insurance and Savings Systems

New forms of insurance and saving have been proposed by several authors as better alternatives than the holding of non-subsistence animals in the herd. As noted in Section 3.3.1.3, the number of non-subsistence animals in Sahelian herds is not apparently great, so that the anticipated reduction of grazing pressure could not be great. However, if the resource base was expanded to such an extent that subsistence holdings did produce surpluses, such insurance and saving systems could help maintain grazing pressure at tolerable levels.

Hjort (1976c) proposed the formation of "cattle insurance blocks". These blocks are essentially low-risk grazing reserves where excess animals could be maintained rather than sold or herded by the household. If the household required replacement animals for the subsistence herd, they could be recouped from the insurance block.

If one views the entire man:animal resource system, Hjort's proposal is for the formation of a special herd with a subsequent specialization of pastoral labor. It would provide a significant increase in security over the current system only if labor-saving technology could be applied in the grazing blocks. The allocation of excess animals to the cattle insurance block must be matched by an allocation of labor as well. If excess animals exist, by implication, labor is relatively scarce. Consequently, little labor will be available for management of the insurance herd. The probability of labor constraints on management is therefore greater, making the installation of labor efficient water sources a prerequisite for success.

Secondly, the aggregation of excess animals into one herd contradicts the traditional risk aversion strategies whereby excess animals are allocated to different herds. The special herd will provide additional security only if it is herded in a less risky environment (i.e. one with higher rainfall). Hjort recognized both the need for a less risky environment as well as the possiblity of commercially exploiting the insurance herd, but he developed neither of these ideas.

The fact that Hjort's proposal requires so many economic prerequisites underlines the fitness of pastoral strategies in the current environment. The need to intensify both resource use and herd management in order to achieve a real improvement in pastoral security is reflected in Goldschmidt's (1975) proposal for "livestock savings banks".

The relation of these banks to pastoralists is similar to that of the insurance block. Pastoralists would deposit excess livestock with the bank and in return would receive a certificate giving the age, sex and bank-assigned serial number of the animal. The certificate would be redeemable at the bank for a similar animal after a specified period of time. The certificate could be sold and its value would float.

According to Goldschmidt, the economic viability of the bank rests on the improvement or creation of two ancillary institutions: a marketing system and a system of feedlots and/or holding ranches. The specialized herd formed from deposits by pastoralists would be commercialized via the maintenance and marketing system, with a certain number of animals withheld from commercialization to meet redemption requirements.

The insurance function would be better performed by the bank than the insurance block, since the bank's herd would be maintained under better nutritional and veterinary conditions. The long term value of the bank will be seen in its ability to maintain animals or otherwise obtain them after a long drought, in order to meet the inevitably high redemption demands. Undoubtedly, this would be an expensive operation. Therefore, it is critical that the bank be economically viable.

The proportion of animals needed for redemption at any one time will obviously affect the economic viability of the bank by fixing the level of commercialization and the amount of working capital. Beyond that, the bank would be competing directly with the traditional marketing system. Shapiro (1979) concluded that the traditional marketing system was as efficient as possible given the environmental conditions. Since the bank has an obligation to its depositors that merchants do not, it must market its animals more efficiently, or must invest revenues in activities with higher rates of return. If the bank is to market more efficiently, it must either invest in infrastructure improvements which reduce animals losses on the way to market, or be able to maintain large numbers of animals for sale at a more favorable seasonal price. The return to these investments is unknown, and consequently, so is the rationality of the entire system.

If one assumes that the livestock savings bank could turn a profit and thereby perform the additional insurance function, the acceptance and use of the bank is contingent on the perception of the bank by the pastoralists. Goldschmidt suggests that pastoralists will be more disposed toward the bank if their leaders are involved in the planning and programming of the bank. The bank must be completely trustworthy, i.e. certificates must always be redeemable at the stated time, even if it reduces short term profits. Once pastoralists are convinced of the integrity of the bank, Goldschmidt feels that their intrinsic economic rationality will lead them to use the bank in numerous ways such as concealment of wealth and provision of collateral.

However, it is important to remember that the bank does not pay interest and performs only an insurance function. The extent to which animals are entered into the bank, thereby relieving grazing pressures, depends on the willingness of livestock owners to forego the animal's annual increment of growth in order to pay for insurance. The proportion of animals entered into the bank would likely be higher among subsistence pastoralists than among non-pastoralists who invest in livestock for the favorable return to capital. The optimal mix of insurance and investment is difficult to evaluate.

6.2.3 Pastoral Cooperatives

If a basic cause of the historic increase in uncertainty is the weakening of the traditional social fabric, the creation of a new web of relationships in the form of pastoral cooperatives may reduce uncertainty. Pastoral cooperatives have been used in Syria (Draz, 1978). While the Syrian cooperatives have a number of goals, they have provided territorial organization which has then induced resource improvement. A national revolving fund for the purchase of feed has also been established, providing a buffer against environmental uncertainty. Attempts in east Africa to organize land directly via the formation of Ranching Associations have not been so successful, largely because the projects aimed at organizing land, rather than the people who used the land (Baldus, 1977).

Swift (1977b) gives a detailed proposal for the formation and operation of pastoral cooperatives. He believes that cooperatives would provide the essential link between man and land that would allow resource improvement. The appropriate geographic and social scale of cooperatives is defined by the transhumance. While Swift states that the spatial projection of the cooperative should include the entire transhumant circuit, in the Sahel it could for the near future include only dry season pasture (Section 6.1.2.1). In a resource context, a pastoral cooperative would be exactly the type of corporate entity required in Section 6.1.1 for the expansion of dry season range by the installation of waterpoints. Since other pastoral groups may contest the attribution of range to certain groups, support for the legitimacy of the cooperatives by the government is imperative.

By virtue of their internal cohesion and their identification with specific ranges, pastoral cooperatives could serve as the vehicles for economic intensification as well. First, as noted above, cooperatives could apply for credit to either open new lands or support themselves while destocking for the initation of a grazing system. Presumably, they would as well enforce internal control of number according to the criteria discussed in Section 6.1.2.1. Cooperatives with capital, either borrowed or constituted from excess animals, could invest in more efficient risk aversion strategies, such as better veterinary services, forage production or millet reserves. Commercial exchanges, both of livestock and of consumer goods could be handled by the cooperative and the profits reinvested in pastoral production. Finally, Swift proposed that cooperatives would provide appropriate social units through which social services, such as education and health services, could be funneled.

If cooperatives provide such potent means of production and protection, one might wonder why indeed they have not evolved in the Sahel. As with grazing systems, cooperatives are unlikely to have evolved since historical evolution has been away from communal activity and toward individual enterprise. As noted in Section 5, this increasing individualism has benefited only a few households with the rest clinging to an increasingly precarious existence. The renunciation of individualism by wealthy owners is unlikely, while among poorer households it requires a radical evaluation of their present situation and realignment of their allegiances. Since vestiges of the traditional society (e.g. Islamic tithes) facilitate a backflow of wealth and mitigate the effects of class formation, the personal and social turmoil of such radical evaluation has been reduced.

It is critical to determine the elements of successful cooperative formation and operation. Certainly the most basic prerequisite of success is a perception by pastoralists that they have economic problems, and that technical solutions to their problems exist but require communal action to implement. The assertion that technical solutions do exist is considered by this author to be correct, yet, as stressed throughout the paper, not proven. Thus the commitment to communal action and away from individual gain, will be greatly affected by the certainty of and delay in obtaining noticeable results (Hamer, 1976).

Equally important to cooperative success is technical and financial support of cooperatives by the government. Anger and Zlataric (1975) make several recommendations, such as the establishment of a single body for the promotion of cooperatives and the adequate provision of credit at fair rates of interest. While government support is crucial, imposition of cooperative structures is counter-productive. The creation of group ranches in Kenya without full participation of the pastoralists identified with the ranches led to a perception of the ranches as simply other resources to be exploited by the household (Hjort, 1976b).

Finally, group solidarity is required for successful cooperative operation. While the efficacy of the technical solutions attainable with cooperatives is one important incentive, a more profound realignment of allegiance away from traditional leaders may also be important. Hamer (1976) studied self-help associations in Ethiopia and found that the prerequisites for success included leaders with alternate cultural links and genealogical heterogeneity among members. Studies of successful cooperatives in Niger showed that leaders of the cooperatives were not identical with traditional leaders (Anger and Zlataric, 1975).

The cooperative must be able to settle disputes and exert authority as well. This function must be well established if cooperatives are to prevent overexploitation of land or financial resources by members within the group. The village social structure itself may be sufficient to achieve this end, as shown in Niger, where loans to villages are more often repayed than loans to individuals (Anger and Zlataric, 1975). In Ethiopia, traditional forms of dispute settlement were incorporated into the self-help association and allowed disputes to be settled within the framework of the group (Hamer, 1976).

Outgroup hostility is also an important factor in the maintenance of group solidarity (Hamer, 1976) and would quickly occur in the Sahel if cooperatives competed with commercial traders. The possibility of disputes between pastoral groups over water and pasture is so severe, however, that the government would have to provide the framework for settlement of these disputes.

Thus, the expansion of the cooperative movement to pastoralism presents donor agencies and governments with some conflicts of interest. The formation of cooperatives implies an accretion of political power that may very well be resisted by local government officials. If cooperatives threaten to restrict access to pastoral resources, non-coop livestock owners such as wealthy residents and government officials will certainly provide outgroup hostility. Thus, the government commitment to cooperatives must be strong but should provide for accomodation with the local elite. Donor agencies, who have recently been exhorted to look more closely at traditional structures, will have to examine those structures for evidence of economic exploitation as well as economic rationality. Furthermore, the reliance on social rather than technical approaches will frustrate some of the bureaucratic goals of both governments and donor agencies (Hoben, 1979).

6.3 Implementation

The nature of the proposed components of pastoral development has important implications for their implementation. The interdependence of environmental improvement and social evolution make a unified approach to pastoral development the most promising approach. In the past, development projects were implemented by the government agency most closely related to the technical inputs offered by the project (Sabry, 1972). Possible synergistic effects of simultaneous inputs were thereby lost. The unification of all development activities under a new agency, as in integrated rural development, is unlikely for political reasons, but the integration of technical inputs from various agencies into a project administered by one agency is feasible.

Pastoral perception has a critical role in all of the components of development. The pastoralists' perceptions of ecological and social problems and solutions will determine their willingness to adopt new strategies. In the past, when projects presented clearly positive opportunities, pastoralists were very willing to adopt new practices (Monod., 1975). Thus the key to increasing pastoral acceptance of new technology is the demonstration of the true benefits and costs of that technology (Baker, 1975). As with the goal of increasing pastoral welfare, an emphasis on demonstrating the value of new techniques would seem trivial, except for the fact that it has seldom, if ever, been done.

While values are not unimportant, distinguishing those values that reflect ecological-economic adaptations from those that do not is very difficult. It is the contention of this author that demonstrations should concentrate on proving the global economic value of new technology (e.g. the impact of a grazing system on the long term security of the household). Only when a higher long term economic return can truly be said to result from an innovation, can planners determine the real shadow price of a social value.

Once the need for demonstration is recognized, the problem of exactly what to demonstrate becomes paramount. The previous sub-sections provide the general outlines of valuable approaches but have also emphasized the unknowns. The change in range conditions to be expected from the grazing system or the return to a livestock bank are critical parameters, yet virtually no data exists for their quantification. The reflex of technical experts is to initiate new research. Yet, research alone is anathema to governments in the Sahel who predicate their existence on their abilities to initiate meaningful change, not new research. Even if research were acceptable, its results would still be suspect until demonstrated. Furthermore, depending on the composition of the research team, the research could quickly become irrelevant without the team realizing it.

The simultaneous needs for the derivation and the demonstration of solutions can be met by using an action planning approach instead of the classic rational planning paradigm (Friedmann, 1969). While a comprehensive discussion of the implications of the action versus rational paradigms is beyond the scope of this paper, the differences in procedure are easily grasped.

Rational planning involves a four-step procedure, beginning with the identification of the problem, then of possible solutions. A "best" solution is selected according to some criteria and is then implemented. The procedure is eminently reasonable in an environment where all the alternatives can be explicitly enumerated, few unknowns are involved and the power for implementation very concentrated. These three conditions are exactly those that render the procedure inapplicable in developing countries.

Action planning, on the other hand, is more a model of human interaction than an intellectual method. It can be conceptualized as a search for a feasible (i.e. effective and implementable) solution involving consultation and experimentation. In pastoral development, action planning would begin with consultations between pastoralists, government officials and technical experts. Such consultation would include discussions of perceived problems and tentative solutions. It would hopefully result in a program that would test the value of the tentative solutions. For example, the value of a grazing system could be determined by establishing several different grazing treatments in an area set aside for that purpose. The execution of the grazing treatments would be performed by the local pastoralists with their herds. Contracts would be established with these pastoralists to define the terms of their participation. Results would be documented in forms such as photography and videotape that clearly portray the benefits and costs of the innovation. Participating pastoralists would be extensively consulted during the treatments for their opinions on both the operation and result of the experiment. When sufficient data was accumulated, a second cycle of consultation would be initiated to examine results and set new directions.

Such experiments-cum-demonstrations would incorporate both indigenous and foreign expertise in providing convincing evidence of ecological potentials. To the extent that potentials can be demonstrated, they will provide an incentive for the creation of social institutions, such as cooperatives, that would maintain the higher productivity.

The role of the social scientist in this process is multi-faceted. He must attempt to identify those values that prevent the adoption of promising new strategies and to determine if these values in themselves reflect a long term survival strategy. He should participate in the design of experiment/demonstrations that allow a determination by the people themselves of the shadow prices of those values. If communal action appears to be appropriate framework for further development, the social scientist should identify those structures of the traditional society that could be reactivated toward this end while preventing further social stratification.

In cases where little traditional basis can be found for just and efficacious communal action, the national government will have to play its most basic function, that of leading its people toward new social values and forms. The performance of this task is by no means assured. While it is the most creative aspect of development, it is the process to which foreign experts can contribute the least. The creation of new forms and the prise de conscience that must precede it are finally the very process of development and can be accomplished only by the people themselves.

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