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CLIMATIC VARIABILITY AND COOPERATION IN RANGELAND MANAGEMENT: A CASE STUDY FROM NIGER

Nancy McCarthy and Jean-Paul Vanderlinden

CGIAR Systemwide Program on Collective Action and Property Rights

Secretariat:
International Food Policy Research Institute
2033 K Street, N.W.
Washington, D.C. 20006 U.S.A.

International Livestock Research Institute
P.O. Box 30709
Nairobi 00100, Kenya

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ABSTRACT

In this paper, we develop an empirical model of an agro-pastoral system subject to high climatic risk to test the impact of rainfall variability on livestock densities, land allocation patterns and herd mobility observed at the community level. Also, because grazing land is a common-pool resource, we determine the impact of cooperation on these decision variables. To capture different abilities of communities to manage these externalities, we construct indices comprised of factors considered to affect the costliness of achieving successful cooperation found in the collective action literature. We then test hypotheses regarding the impact of rainfall variability and cooperation using data collected in a semi-arid region of Niger. Results indicate that rainfall variability first leads to higher and then lower stock densities, indicating that benefits of accumulating large herds in variable environments are eventually offset by the higher risks of low production and higher mortality. Communities with characteristics hypothesized to favor cooperation have lower stock densities and greater herd mobility. Neither cooperation nor rainfall variability has a significant impact on the proportion of land allocated to crops vs. common pastures.

Keywords: rangelands, environmental risk, natural resource management, pastoralism, collective action, cooperation, institutions, livestock stocking densities, mobility, Niger

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CLIMATIC VARIABILITY AND COOPERATION IN RANGELAND MANAGEMENT: A CASE STUDY FROM NIGER

1. INTRODUCTION

Nancy McCarthy[1] and Jean-Paul Vanderlinden[2]

Rainfall variation is often identified as the major risk faced by agro-pastoralists in the arid and semi-arid regions of sub-Saharan Africa (Swallow 1994). In these environments, households must adopt mechanisms to manage the variability in production of crops and livestock, and to mitigate the impacts of drought when it does occur. Among the many risk management strategies that have been identified, livestock mobility is often seen as one of the most valuable, since it enables herders to improve mean output as well as decrease output fluctuations associated with both spatial and temporal variability in rainfall (e.g. Fleuret 1986; Painter et al. 1994; Swallow 1994; van den Brink et al. 1995). Mobility is facilitated by the common-pool nature of most grazing resources, which significantly reduces the transactions costs associated with mobility (Niamir-Fuller 1999). But the common-pool nature of grazing resources also means that there are potential externalities, which lead to costs associated with resource management. These externalities, and the extent to which they are managed, will also affect decisions on stock densities observed on home pastures, herd mobility, and land allocation patterns. The purpose of this paper is to develop an empirical model that incorporates the impact of both rainfall variability and costly cooperation on land use,

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[1] Nancy McCarthy: Research fellow of IFPRI (International Food Policy Research Institute), Washington DC and ILRI (International Livestock Research Institute) Nairobi.

[2] Jean-Paul Vanderlinden: Adj. Professor, Department of Geography, University of Moncton, Canada.

land allocation and herd mobility decisions, and to apply the model to data collected in southwest Niger.

Issues surrounding the impact of climatic variability on the use and management of common resources, the vulnerability of rural households, incentives for privatization, and conflicts among resource users are widespread throughout sub-Saharan Africa; and are in fact still quite important in North Africa, and West and Central Asia. In Niger, the government began implementing a new rural code in 1993 that attempts to re-define the access, use, and management of natural resources in Niger (Secrétariat Permanent 1993 1997), though it appears that implementation has stalled (Kirk and Ngaido 2001; Ngaido 1995; Gado 1996). While it is widely recognized that climatic variability is an important characteristic underlying the logic of the agro-pastoral system, designing a legal framework that addresses the need for flexible access while maintaining incentives to use and manage the resource have yet to be developed. Results in this paper should help shed light on these wider issues.

A short review of the literature specific to Niger is presented in the second section. This is followed by a review of the theoretical literature on common property, resource management, mobility, and risk, leading to a proposed model of pastoral production systems. In the third section, we discuss survey methodology and present descriptive statistics for sample communities. Results from model estimation are presented in the fourth section. We conclude by discussing policy implications and extensions to the existing model.

2. PROPERTY RIGHTS AND AGRICULTURAL PRODUCTION IN NIGER

HISTORICAL OVERVIEW

The impact of colonization on the property rights structure of agricultural land has taken several forms. The nationalization of the "terres vacantes et sans maître" in Francophone coastal west Africa and their subsequent dedication to cash crop production led to a profound transformation in land rights, which were imposed by the colonial power. Nevertheless, the impact of the French rule in Niger on agricultural land tenure, particularly in the more arid regions, was less pronounced than in the highly productive coastal regions. This can be explained by the fact that Niger, because of its unfavourable environmental conditions, was mainly seen as a reservoir for labour meaning that land was a secondary concern for the colonial power (Raynault 1988). When considering rangeland, it is difficult to assess the impact of the colonial rule in Niger on tenure *stricto sensu*; however, one must note that the colonial power did have an impact on pastoralists' traditional social structures and institutions (Starr 1987).

Originally, land tenure in Niger's agro-pastoral area was characterized by the existence of three different types of tenure status. Up to the time of independence, landowners, composed of aristocratic and warrior families, held a primary ownership right to village land; this would include, for example, the village chiefs and their lineage, and canton chiefs and their lineage. Chiefs could allocate land and receive the payment. Their control over land was attributed to the fact that they were members of families who arrived first on the land considered. Use-rights holders formed a second group. Having a secondary ownership right (they received land from the village and canton chiefs), they had to pay tithes. Their use-right was secure and could be inherited by their children. A third group was formed by tenant farmers renting fields, who were vulnerable because the owner could reclaim his field at any time (Ngaido 1993).

Following independence, the first regime (Hamani Diori 1960-1974) abolished tithe payments and recognized customary ownership. This created two classes of land owners: nobles and aristocrats who saw their customary rights recognized and who therefore could alienate land in their possession, and the use-rights holders and tenants who, through the suppression of the payment of the tithe, were considered *de facto* owners (non payment of the tithe being the sign of ownership), but who could not alienate or divide their land (Ngaido1995). It must be noted however, that a majority of tenants and use-right holders continued to respect their traditional obligations and were therefore not considered as owners. The second regime (Seyni Kountché 1974-1987; Ali Saïbou 1987-1990) introduced a "land to the tiller" policy that was supposed to increase tenure security to use-right holders and tenants, but was not supported by any legislation (Ngaido 1995). Again, many use-right holders and tenants kept on paying the tithe, in essence showing that they were not owners. Following the demise of Kountché's military regime, traditional landowners began to reclaim land that was lost during the "land to tiller policy period"; their task was facilitated by the lack of legal framework supporting this policy. The final result of these successive reforms has been confusion in terms of land tenure, generating tension and increasing conflicts over land tenure (Ngaido 1995). Presently, while an initiative (the rural code) to redraft land tenure related legislation is being implemented (stalled according to some; e.g., Gado 1996), village and canton chiefs remain *de facto* the principal authority regarding land allocation decisions; and customary tenure arrangements still prevail in most areas of the country (Gavian and

Fafchamps 1996). In terms of tenure security, owners and use-right holders can be considered as having secure tenure over land, while tenants always face the risk of losing their fields.

There are two major zones in Niger, the "zone de modernization pastorale" where cropping is prohibited, and "zone agropastorale", where both cropping and livestock production are allowed. Rangeland had consisted, up to independence, of uncultivated areas under the control of the village chief (fallow) or canton chiefs (land that had never been cultivated). These lands were considered as "terres de chefferies". Under the Diori regime, the "terres de chefferies" were nationalized when never cultivated in the past, or were considered as common village land when in fallow (Ngaido 1993). Under the Kountché regime, the nationalization of virgin land was confirmed while the status of fallow land was left unclear. After the Kountché regime, more rangeland was allocated to farmers (for cropping) by village chiefs. This allowed the traditional authorities to assert their "traditional right" over these lands (Ngaido 1993). Thus, at the present time much of Niger's rangeland is under the control of groups with a strong agricultural tradition.

Concerns have also been raised about the impact of development policies on land use and land allocated to the range. An example of development policy that has been under scrutiny is the "terroir" approach. The "terroir" concept is an approach to land use planning that has, in recent years, been favored by French development agencies and by governments of former French colonies in the Sahel (Elbow 1996). The concept of "terroir" is originally an analytical unit describing the physical space on which sedentary villagers get most of their means of subsistence. This analytical unit is now used as an intervention unit in a drive to give rural communities greater responsibility in the management of their resources. However, because it has essentially been used as a concept linked with sedentary agriculture, the concept of “terroir” may not be useful when considering households where at least some members practice relatively mobile lifestyles (Painter et al. 1994; Marty 1996). There may be a real risk that the exclusion of mobile populations from the current mainstream development paradigm will further transform land tenure arrangements that were traditionally adapted to mobility (existence of corridors for transhumant livestock, for instance). Whether or not it is “better” to promote this transformation unfortunately remains an open question. At the very least, people dependent on mobility will suffer losses, and some mechanisms for fairly handling such cases need to be put in place, or there will likely be a continuance – or even an escalation – of violent responses to this transformation.

THE POPULATION-ENVIRONMENT NEXUS

Land tenure systems mediate the relationship between humans and the resource (Schlager and Ostrom 1992). Once this relationship is under stress, the mediating institution is also under stress. For instance, Grégoire (1982) shows that the increasing population led to an increase in cultivated area in the village of Gourjae (eastern Niger). This change put stress on the local land tenure system and led to an adaptation of pastoral practices and the creation of rainy season livestock corridors, thus changing some of the rules regarding land use. However, in many situations, the local land tenure system and rules regarding use have not changed, again leading to conflicts over claims to resources and most likely to poorer management of those resources.

When population increase occurs in an area prone to drought and desertification, it may lead to further degradation of the land resource base (Arrignon 1987, pg. 4,7-22; Agnew 1995). Increased population combined with a decrease in the quality of the land resource can lead to greater relative and absolute scarcity of agricultural land. Agriculturalists then claim more cropland, pushing pastoralists onto every more fragile and marginal land.[3] The effect of the population growth in the semi-arid areas of the Sahel has been exacerbated by a trend of increased rainfall variability and a decrease in absolute rainfall quantity.

To summarize, the current situation of land tenure in Niger is characterized by traditional tenure arrangements that are facing challenges posed by population increase, by unfavorable changes in climate, and by the changing political environment. Because the data used below was collected during one period of time, however, we will not be able to isolate those factors that affect all communities at any given point in time, such as the political environment. Instead, we focus on those factors that differ among communities in order to ascertain the impact of cooperation, climate, and profitability on land use and resource management.

[3] See Cleaver and Schreiber 1994, 21-24; and for detailed Nigerien case studies see and Banouin, et al. 1996.

3. MODEL DEVELOPMENT

The model developed in this section focuses on three choice variables within this system of land use and allocation: total stock densities on community pastures, the proportion of the total herd that migrates to non-community pastures, and the allocation of land to crops and to pasture. Data for all of these variables were collected at the community level. One might consider that each of these decisions is an individual decision and that levels observed at the community-level are simply the sum of household level decisions. In other words, we observe outcomes at the community level that are simply the result of a non-cooperative game being played at the household level. In this paper, however, we hypothesize that communities may in fact cooperate. In sample communities, we do not observe formal rules and regulations over herd mobility or the use and allocation of land. Nonetheless, we hypothesize that observed patterns of land use (including stock densities on home pastures and herd mobility) and land allocation will be a function of a community-level maximization problem which incorporates both individual incentives to cooperate and community characteristics hypothesized to lower costs of cooperation, following the theoretical model of costly cooperation developed in McCarthy et al. 2001.

In order to clearly highlight the impact of various explanatory variables on each decision variable, we consider each decision variable in turn and then present the full model and the resulting system of equations to be estimated.

Stock Densities

Under any pasture management regime, stock densities will be a positive function of the underlying productivity of the range resource and the relative profitability of livestock production vis-à-vis alternative activities such as cropping. Following the Boserup (1965) hypothesis, we also include population density as explanatory variable to capture the possibility of intensification-driven changes in productivity.

Standard non-cooperative, one-period game models of use-rates of common rangelands give the result that use rates are greater on the commons than would be the case under the social optimum, and that the degree of overexploitation increases with the number of members (Dasgupta and Heal 1979). Given that formal rules and regulations do not exist in any of the communities studied, then following the non-cooperative model, overexploitation should be captured by solely by the number of members. However, there is a large body of empirical evidence to support the notion that communities are unlikely to either fully cooperate or completely not cooperate (Ostrom 1990; Oakerson 1992; Baland & Platteau 1996). In other words, observed outcomes in a community are not likely to be the result of a binary choice between perfect cooperation and no cooperation, but rather a function of variables often posited to affect the "successfulness" of cooperation that have an impact on the margin.

In a theoretical model of costly cooperation developed in McCarthy et al. (2001), equilibrium use levels are directly affected by profit variables and the number of members – but an indirect effect also arises via an impact on community-level capacity to cooperate, which shift equilibrium use levels – in our case, stock densities. This is an important point since we do not have a direct measure of community capacity itself. For those variables hypothesized to affect only community-level capacity to cooperate, we construct an index of this capacity, which is developed in section 5 below. Another subset of variables, however, is hypothesized to affect stock densities directly and indirectly through community capacity, so that the hypothesized impact of these variables is ambiguous where the direct and indirect impacts have opposite signs. For instance, increased profitability is hypothesized to have a direct positive impact on stock densities, but also an indirect negative impact because costs of cooperation decrease (McCarthy et al. 2001). An increase in the number of members at first reduces costs of cooperation because of lower fixed costs per member, but at some point, higher transactions costs of making and enforcing agreements, and greater marginal costs due to greater cumulative incentives to cheat, lower relative gains to cooperating and thus lead to higher stock densities directly and indirectly.

While socio-cultural heterogeneity is hypothesized to affect only community-level capacity to cooperate, economic heterogeneity may affect both capacity and stock densities directly. First, we hypothesize that heterogeneity in terms of different marginal costs, wealth levels, cash constraints, etc., reduces the scope over which mutually beneficial agreements might be made thereby making cooperation more costly (Alesina and La Ferrara 1999; Johnson and Libecap 1982). Following Baland & Platteau (1997), the direct impact of economic heterogeneity on stock densities is ambiguous.

Turning now to rainfall variability, as noted above, a group of researchers have posited that herders will (attempt) to hold onto more livestock in high variability environments. The reasoning here is that larger herd sizes going into a drought is thought to imply a greater probability of coming out of the drought with more animals (Livingstone 1991; Fafchamps 1998; Niamir-Fuller 1999)[4]. Similarly, according to

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[4] This line of reasoning ignores the fact that even though such a strategy might be rational when pasture is either perfectly managed or held as private land, the extent of herd build-up may be significantly greater when pastures are not perfectly managed.

proponents of the “new range ecology”, the rationale for holding larger herd sizes is greater in high variability, “disequilibrium” environments since in these environments forage productivity is driven almost exclusively by rainfall, with limited or no impact of stock densities on future forage productivity (c.f. Behnke et al. 1993). Conversely, another school of thought hypothesizes that stock densities will be lower in high variability environments; this hypothesis basically stems from the assumption of risk-averse producers and holds even when a non-cooperative game framework is used to analyze the decision problem. Sandler and Sterbenz (1990) and McCarthy (1999) show that increased variability will lead to lower stock densities under any property rights regime. One of the main hypotheses to be tested below, then, is the sign of the impact of rainfall variability on stock densities, and also to test if there is a different effect in communities with relatively high variability – a coefficient of variation of about .3 – as proposed by the new range ecology.

To summarize, stock densities are hypothesized to be a function of variables affecting profitability, population density, number of community members, heterogeneity, variables directly affecting the cooperative capacity of a community, and rainfall variability. The null hypotheses are as follows: 1) profitability variables have a positive impact on stock densities, implying that the direct impacts on stock densities are stronger than indirect impacts on cooperation; 2) higher population densities lead to higher stock densities because of intensification-induced increases in animal productivity, 3) the number of community members increases stock densities, implying that direct effects on stock density and the variable costs of cooperation outweigh declining fixed costs of cooperation; 4) heterogeneity in economic characteristics has a positive effect on stock density primarily through the negative impact on cooperation; 5) lower cooperative capacity will unambiguously lead to higher stock densities, and 6) that stock densities will be a negative function of rainfall variability.

Mobility

As detailed above, many researchers have discussed the benefits of mobility in capturing the value of *ex post* adjustments to actual rainfall realizations for the individual herder (van den Brink et al. 1995; Thompson and Wilson; 1994), but few economic models have considered the incentives for individual herders to engage in mobility when one's own choice on mobility is affected by the choices of others who share access to the same pastures at home. Freudenberger and Freudendberger (1993) discuss patterns of mobility observed in the Ferlo region of Senegal. They argue that the individual's decision to engage in mobility depends on how many others remain at home. The description implies that the structure of incentives to engage in mobility resemble a chicken game. Under "normal" rainfall conditions, each herder would prefer to stay at home while at least a certain fraction of others migrate, but the herder also prefers to move in the case where no others do so. Under other rainfall conditions, however, all community members may prefer to be mobile or all stay at home, so that the fraction moving in any given period will depend on relative rainfall realizations across the region of "potential" mobility. Mobility will also be a function of relative differences in underlying pasture productivity, the transactions costs of mobility, and the number of members within a community.

With respect to economic heterogeneity, it is quite possible that wealthier herders may have a dominant strategy to always move, whereas poorer herders may have a dominant strategy to always remain at home, as discussed in Ruttan (2000). As the number of members increases, the probability that wealthier herders now find it profitable to move increases, since profits on the home area will decrease as the number of community members increases but profits accruing to the herder engaged in mobility do not change when the number of members increases.[5] Thus, the fraction of herders moving in any period will also be a positive function of the extent of economic heterogeneity.

To summarize, we hypothesize that: 1) the higher the relative rainfall realizations at home, the lower will be herd mobility, 2) the greater the cooperative capacity, the greater herd mobility, 3) the better the underlying resource base, the lower herd mobility, and 4) the greater the transactions costs involved in mobility, the lower mobility, and 5) the greater economic heterogeneity, the greater mobility.

Land Allocation

The final decision is the allocation of land between usufruct (*de facto* private) cultivation by individual households and common – or open access – pastures. The decisions by community members on stock-days plus the extent to which community pastures area accessed by outsiders determine the pasture use-rates and therefore the marginal productivity of land allocated to pastures. This resulting productivity will be equated to that arising from cultivation. In addition, even if there is perfect cooperation over stock densities on community pastures, there will be a tendency to under-provide

[5] We are thus assuming that the available pasture in the "rest of the world" is not subject to the same negative externalities that characterize use of home pastures.

land to the commons meaning that the number of members has both a positive direct effect on land allocated to crops, and an indirect positive effect via stock densities to the extent that the latter are overexploited (de Janvry et al. 1998). Put differently, allocating land to the common pool is similar to providing a public good, and as such, there will be a tendency to under-provide that good irrespective of how the land is used. If members know that the common pool pastures will subsequently be overexploited, then there will be a tendency to reduce the allocation of land to the common pastures because of how land will be used, once allocated. These are two distinct effects, often referred to as provision and appropriation (de Janvry et al. 1998). As with stock densities, population density may lead to intensification of agricultural production through the adoption of productivity enhancing investments or changes in practices. It may also induce greater intensification of crop-livestock interactions that may in turn lead to more land allocated to crops and higher stock densities. To the extent that population density induces livestock-specific intensification, however, we may expect less land allocated to crops but greater stock densities. The theoretical impact of population density is thus ambiguous. The impact of crop/livestock prices is also ambiguous; the sign depends on the nature and strength of crop-livestock interactions. Finally, we hypothesize that a greater number of crop-specific assets, such as plows, granaries, carts, etc., increases land allocated to crops at the level of the community. Though such assets are held by individuals, we argue that rent and share arrangements are sufficiently well-developed that this variable captures the available supply of crop-specific assets at the community level.

With respect to rainfall, to the extent that livestock is less variable than crops, it would seem trivial to show that greater land would be allocated to livestock versus crops in higher variability environments. However – as so often happens with models incorporating multiple co-variate risks – the sign is actually ambiguous (McCarthy 1999). This arises due to externalities generated from the use of common pastures that do not arise under individual crop farming. The presence of both crowding and risk externalities has a positive impact on the proportion of land allocated to individual crops vs. common pastures because of individuals' incentives to minimize this externality, *ceteris paribus*. Nevertheless, the overall impact of rainfall variability on land allocated will also be a function of the mean level of rainfall. We thus hypothesize that, in this semi-arid region, the overall impact of rainfall variability on cropland is negative whereas the impact of higher rainfall on cropland is positive.

To summarize, we make the following hypotheses: 1) greater negative externalities generated on common pasture lead to a greater proportion of land allocated to crops, 2) larger membership in the community also leads to more land allocated to crops, 3) population density will lead to more land in crops when density-driven intensification favors productivity improvements in crops vs. livestock, 4) higher relative crop/livestock prices increase cropland, 5) more crop-specific assets held within the community and more infrastructure increase cropland, and 6) higher mean rainfall leads to more cropland whereas greater rainfall variability reduces cropland.

The Model:

Incorporating the arguments presented above leads to the following specification for the maximization of expected utility (*EU*):

$$\max_{Mob,SD,L_{Crop},L_{Pasture}} EU = f\left(Mob, SD, L_{Crop}, L_{Pasture}; Coop, Z^{Climate}, Z^{Comm}\right)$$

$$s.t.\ L_{Crop} + L_{Pasture} \leq L_{Tot} \tag{1}$$

where:

Mob = Proportion of the community herd migrating to outside pastures during the rainy and dry seasons, weighted by length of season

SD = stock densities, measured in tropical livestock units per hectare of community pastures,

L_{Crop} = proportion of community land allocated to crops

$L_{Pasture}$ = proportion of community land allocated to pastures

L_{Tot} = Total land constraint

Coop = Cooperative capacity of a community (described more fully below)

$Z^{Climate}$ = climate characteristics, including:

- $\bar{R}_{Home}$ = average rainfall at home
- CoV_{Home} = coefficient of variation of rainfall at home
- $R^{96}{}_{Home}$ = rainfall received during the previous rainy season

Z^{Comm} = community -level characteristics, including the following:

- *THH* = total number of households in the community
- *HHph* = number of households per hectare
- *TluHet* = coefficient of variation in livestock holdings, measured in tropical livestock units (tlu)
- *CostM* = cost of mobility
- *RQ* = range quality index

Plm	=	relative price of livestock to millet
Di	=	distance to the nearest regional livestock market

C-AgAssets = the number of crop-specific assets in the village, including oxen, ploughs, transport carts, and crop storage facilities.

Assuming that risk preferences can be captured by the mean and variance in rainfall, that induced innovation can be captured using population density as a proxy variable, and that the land constraint holds with equality leads to the following set of demand equations:

$$Mob = f\left(SD, L_{Crop}, R^{96}_{Home},\ THH,\ Coop,\ TluHet, CostM\right) \tag{2}$$

$$SD = f\left(Mob, L_{Crop}, \overline{R}_{Home},\ CoV_{Home}, THH,\ Coop,\ TluHet, HHph, Plm,\ Di, RQ,\right) \tag{3}$$

$$L_{Crop} = f\left(SD, Mob, \overline{R}_{Home}\ ,\ CoV\text{ - }R_{Home},\ THH, Coop, HHph, Plm, Di, CAgAssets\right) \tag{4}$$

In the estimated equations above, we use long-term average rainfall for both land allocation and stock densities, but rainfall during the preceeding rainy season as an explanatory variable in herd mobility equation. Essentially, we are assuming that both stock densities and land allocation reflect expectations over rainfall. While this is not a strong assumption for cropland, an explanation is needed to justify the assumption for stock densities. Given that stock adjustments to adverse rainfall shocks are likely to exhibit lags, we need to consider where we are in terms of "drought cycle". In the region where the case study communities are located, the year 1990-91 was the last year for which rainfall was below two standard deviations for any of the communities.[6] We thus assume that any adjustments to stock levels had been made by 1997-98, the period to which the survey referred. Mobility, on the other hand, is hypothesized to be the *ex post*

[6] We did use a dummy to indicate whether or not a rainfall shock had occurred in the preceeding 5 years, but the coeffiient was not significant in either the stock density or land allocation equations.

adjustment mechanism to deviations in expected rainfall realizations each year, following van den Brink et al. (1995). Unfortunately, given that we have a cross-sectional data set, we cannot directly test the impact of rainfall variability on mobility, which would require a panel data set.

4. COMMUNITY SURVEYS AND DESCRIPTIVE STATISTICS

Monthly rainfall data was collected at 17 rainfall stations for the period 1985 – 1996; and a list of all communities within a 50 km radius of each station was drawn up. Forty community names were randomly drawn from this list. Data was collected at the village level, the primary contact was the village chief, and one of the authors was present at every interview. Price data was collected at markets identified as the primary markets used by community members. For the interested reader, a full description of data collection methodology is presented in Appendix 1. In three communities, the topography made it virtually impossible to adequately measure total land area and/or to complete the range quality assessments, so that the remaining sample consists of 37 communities. Descriptive statistics for the endogenous and exogenous variables are presented in Table 1 below.

Table 1—Descriptive statistics

	Mean	Std.Dev.	Min.	Max.
Endogenous Variables				
Mobility (proportion of year)	.18		0	0.42
Stock Density (TLU per hectare)	.74		.01	4.68
Proportion of Land in Crops	.33	.16	.09	.42
Climate Variables				
Average Rainfall	498.23	90.68	335.70	649.81
Coef. of Variation of Rainfall	.23	.06	.08	.37
Rainfall in 1996	567.05	109.18	429.75	750.83
Cooperation Variables				
Total Households	99.51	70.40	20.00	307.00
Coef. of Variation of Livestock Holdings	1.18	.83	.25	4.50
Coef. of Variation of Millet Yields	.33	.36	.08	2.22
Number of Ethnic Groups	1.62	.89	1.00	4.00
Proportion of Households not of Ethnic Majority	.05	.11	0	.42
Proportion of Households with Migrants	.48	.20	.06	.83
Use of Community Pastures by Outsiders in Rainy Season (number of animals)	590.37	1151.29	121.00	4050.00
Use of Community Pastures by Outsiders in Dry Season (number of animals)	128.32	350.58	0	1800.00
Transhumant Herd Sizes	2408.92	3600.00	0	10,000.00
Production/Profitability				
Range Quality Index	1.49	.69	0.01	2.73
Relative Price of Livestock to Millet	1.31	.24	.87	1.60
Distance to Market (kms.)	32.68	22.64	1.00	79.00

In sample communities, the proportion of herds that were mobile during the crop year 1996-97 ranged between 0 and 42% with an average of 18%; though it should be noted that rainfall during the summer rainy season of 1996 was higher than average in all but one of the communities. Average stock densities on home pastures are fairly high at ¾, though it should be stressed that this figure does not take into account mobility. Even so, only seven communities have densities greater than one and median density is just .3. Various estimates of carrying capacity in "normal" years in the Sahel range between .13-.25 for the ranges falling on the 400 mm rainfall isohyet (de Leeuw & Tothill 1993, pg. 78); we suppose that these would be somewhat higher in the study area since average rainfall is higher than 500 in 18 of the communities. Thus, the descriptive statistics indicate little evidence of dramatic overstocking in general. Cropland accounts for 33% of total community land on average, ranging from about 10 to 42% in sample communities.

There is a good deal of variation in the total number of households within a community, though there are less than 2 ethnic groups per village indicating a relatively homogeneous ethnic composition of villages on average. However, there is great deal of variation in livestock holdings within communities. The coefficient of variation in livestock holdings is 1.18; household harvests of millet also vary, but not nearly as much as captured in the coefficient of variation of .33.

5. DATA ANALYSIS

Before proceeding to the econometric estimations, we first consider how to capture the "cooperation" variable. As noted above, in none of the study communities were there explicit rules on maximum stock levels held by households, total stock densities at the community level or mobility. However, we also know that, being largely dependent on livestock products, community members do meet and discuss the condition of the animals, the weather, and pasture. Because we have no direct measurements of the capacity of the community to cooperate, we instead use factors that have been hypothesized to affect the level of cooperation reached in any community (c.f. Ostrom 1990; Baland and Plateau 1996; Berkes and Folke 1998). These variables can be categorized as follows: 1) those that affect the ability of the community members themselves to appropriate any benefits associated with reduced stock densities (as opposed to non-members also gaining benefits), 2) those that affect the capacity to negotiate and supervise members' actions, and 3) those that affect the ability of members to reach mutually beneficial agreements amongst themselves. To capture these effects, we derive an index that includes the following variables corresponding to the above categories: 1) stock levels of neighboring villages using community pastures in the rainy season (*RsIN*) and in the dry season (*DsIN*), and dry season stock levels of transhumants (*Transh*), 2) the percent of households where the head of household migrated for work in the past year (*MigW*), and 3) three indicators of heterogeneity. The first indicator of heterogeneity is the coefficient of variation measure based on information provided on the smallest, largest and average harvests. While landholdings would have been preferred, only information on differences in total harvests is available. It is hypothesized that large differences in wealth reduce the range over which common agreements can be formed (Alesina and La Ferrara 1999). The second and third are measures of the ethnic heterogeneity, captured by the number of ethnic groups in a village and the proportion of households that are not a part of the ethnic majority. We hypothesize that ethnic heterogeneity may make informal cooperation, based largely on social norms, more difficult.

One way to capture the effect of these variables is to simply include all of them in the estimated equations. However, there is a great deal of correlation among these variables, which poses serious estimation problems given the sample size. Thus, we used a factor analysis – specifically, iterated principal factors -- to construct indices. Results for the first two factors, which had eigenvalues greater than 1, are presented below.

	Factor 1	Factor2
Eigenvalue	1.56	1.23
Cumulative	.43	.77

Scoring Coefficients	**Factor 1**	**Factor 2**
Coef. of Variation in crop yields	-.02	.57
Number of Ethnic Groups	.51	-.08
% Not of Ethnic Majority	.27	.06
Average Number of Households with Members Migrating for Wage Work	-.06	.09
Dry Season In-Migration	.27	-.04
Rainy Season In-Migration	.12	.37
Transhumants In-Migration	.09	-.03

The first factor has relatively high and positive coefficients on variables representing pressure on home resources by non-community members, as well as high and positive scores on the ethnic heterogeneity variables. Migration and heterogeneity in cropland holdings have negative but relatively small coefficients. We interpret this variable as capturing factors that make cooperation more difficult, particularly with respect to the use and management of home pasture resources, and refer to it hereafter as

$Cost1_{Coop}$. The second factor has high and positive coefficients on heterogeneity in cropped land and rainy season in-migration, and to a lesser extent, migration for wage work. We consider this variable to capture the factors that make cooperation more difficult particularly for managing crop-livestock interactions. We hereafter refer to the variable as $Cost2_{Coop}$.

We now return to the model developed in section 2, and attend to some practical difficulties in estimating the model. First, the structural model developed above requires estimating a system of simultaneous equations. Given the data, we must estimate a reduced form model. Second, we must specify an econometric model to test hypotheses regarding overexploitation and cooperation. Theoretically, the extent of overexploitation will be a function of the number of households. Cooperation may offset – at least to some extent -- the impact of the number of members, but there are a number of empirical specifications that can capture these effects. We considered three specifications. In the first specification, we include only the total number of households. Under the assumption of either complete cooperation or non-cooperation, a significant and positive coefficient on the number of households supports the non-cooperative hypothesis. However, even if the coefficient is positive, we have no statistical capacity to test whether non-cooperation is "complete" under this specification. In the second specification, we include total households and the cooperation costs indices, $Cost1_{Coop}$ and $Cost2_{Coop}$, to allow for differing "levels" of cooperation to be reached across communities. In the third specification, we drop the total household variable, and instead include interaction terms composed of the cooperation cost indices multiplied by the number of households ($Cost1_{Coop}HH$ and $Cost2_{Coop}HH$). The second and third specifications perform quite similarly, so we present only the results from the second specification in the text below.

We also would like to test whether or not the coefficient of variation in rainfall has a different effect in areas with relatively high vs. relatively low rainfall variability. The new range ecology literature suggests that areas exhibiting coefficients of variation greater than .3 may be characterized as "disequilibrial". Given the rather short-term nature of our rainfall data, we have only 6 communities with coefficients of variation greater than .3; there does appear to be a distinct "break" between communities above and below .25, however. The theory provides only rough guidance for the exact functional form to use to distinguish between areas, but range ecologists consider the case study area to be one that may exhibit both equilibrial and disequilibrial rangeland. We estimated the equations using the coefficient and the coefficient squared, and we also estimated the equation using the coefficient, a dummy for high variability areas, and an interaction term to capture different slope effects. In the estimations presented below, we present results using the coefficient and its square; results for the shift and slope dummies are quite similar but less efficient.

Next, mobility was not undertaken in 15 of the 36 communities, and so we estimate this equation as a tobit. Also, we use total rainfall received during 1996 to capture the ex post adjustment nature of mobility instead of the ratio between actual rainfall at home to actual rainfall in the areas of potential mobility. We assume that herders in sample communities have access to the same sites in the outside world, so that denominator in the home/away rainfall ratio is the same for all communities.

Incorporating these considerations leads to estimated equations are given below for the specification capturing an multiplicative impact of cooperation costs and households:

$$\begin{aligned} Mob = \; & \beta_0 + \beta_1 R^{96}{}_{Home} + \beta_2 \bar{R}_{Home} + \beta_3 CoV\text{-}R_{Home} + \beta_4 CoV^2 + \beta_5 Cost1_{Coop} HH + \beta_6 Cost2_{Coop} HH \\ & + \beta_7 TluHet + \beta_8 HHph + \beta_9 Plm + \beta_{10} Di + \beta_{11} RQ + \beta_{12} EthnM + \beta_{13} CAgAssets + e_1 \end{aligned} \tag{5}$$

$$\begin{aligned} SD = \; & \gamma_0 + \gamma_1 \bar{R}_{Home} + \gamma_2 CoV\text{-}R_{Home} + \gamma_3 CoV^2 + \gamma_4 Cost1_{Coop} HH + \gamma_5 Cost2_{Coop} HH \\ & + \gamma_6 TluHet + \gamma_7 HHph + \gamma_8 Plm + \gamma_9 Di + \gamma_{10} RQ + \gamma_{11} EthnM + \gamma_{12} CAgAssets + e_1 \end{aligned} \tag{6}$$

$$\begin{aligned} L_{Crops} = \; & \delta_0 + \delta_1 \bar{R}_{Home} + \delta_2 CoV\text{-}R_{Home} + \delta_3 CoV^2 + \delta_4 Cost1_{Coop} HH + \delta_5 Cost2_{Coop} HH \\ & + \delta_6 TluHet + \delta_7 HHph + \delta_8 Plm + \delta_9 Di + \delta_{10} RQ + \delta_{11} EthnM + \delta_{12} CAgAssets + e_1 \end{aligned} \tag{7}$$

The only difference for the additive specification is that $Cost1_{Coop}HH$ and $Cost2_{Coop}HH$ in the above equations would be replaced by $Cost1_{Coop}, Cost2_{Coop}$ and THH .

The reduced form makes interpretation of the coefficients difficult when a variable in the structural model appears in more than one equation, since in the reduced form, the variable then picks up both direct and indirect effects. For instance, non-cooperation should increase stock densities which should indirectly increase mobility, but the direct impact of non-cooperation should be to reduce mobility. We consider these direct and indirect impacts when discussing estimation results below.

All variables are defined as above, with the exception of the costs of mobility. Of course, there are no market prices for the costs of mobility. Instead, we use a dummy variable for whether or not the ethnic majority in the community is from a traditionally pastoralist tribe (*EthnM*), which is hypothesized to reduce costs of mobility via access to more dense and sophisticated networks. Regression results are presented in Table 2.

Table 2--Regression results

	Non-cooperation Mobility		Stock Density		%Land Crops		Cooperation Costs, Additive Mobility		Stock Density		%Land Crops	
	Coef.	P-val.	Coef.	P-val.	Coef.	P-val.	Coef.	P-val.	Coef.	P-val.	Coef.	P-val.
Constant	-4.79	.24	-34.90**	.01	.-.04	.98	-6.12*	.09	-35.41**	.00	.18	.91
Climate Variables												
R^{96}_{Home} (nl)	-.002*	.09					-.003**	.01				
$\overline{R}_{Home}$ (nl)	.63	.36	4.41**	.02	.06	.82	.76	.22	4.65**	.00	-.005	.98
$CoV - R_{Home}$	10.78**	.02	23.61	.16	1.53	.48	15.75**	.00	31.84*	.01	1.54	.45
CoV^2	- 24.26**	.02	-36.05	.19	-4.46	.36	-37.14**	.00	-58.85**	.05	-4.67	.36
Cooperation Variables												
THH (nl)	.13	.13	.39	.36	.0004	.99	.13*	.10	.06	.87	.02	.76
$Cost1_{Coop}$							.16**	.01	.44*	.10	-.002	.95
$Cost2_{Coop}$							-.30**	.01	.78**	.00	-.07**	.04
TLUHet	.04	.53	.61**	.01	-.05	.12	.15**	.04	.34*	.06	-.02	.42
Production/Profitability												
HHph (nl)	.08	.17	.98**	.00	-.09*	.06	.10*	.06	1.03**	.00	-.08*	.06
RQ	.08	.31	.41	.20	.07	.11	.13*	.06	.43	.22	.07*	.09
Plm(nl)	.40	.25	-.38	.14	.14	.48	1.01**	.01	-1.73	.14	.28	.11
Di (nl)	-.08	.16	-.76**	.04	-.01	.76	-.04	.40	-.50**	.02	-.02	.48
EthnM	-.01	.94	.66	.35	.11	.32	.04	.72	.67	.35	.12	.25
CAgAssets	.05	.80	.07	1.44*	.04	.61	.50**	.04	.07	.93	.20*	.09
Sigma	.22						.35					
Adjusted R2			**.63**		**.36**				**.74**		**.42**	
Pseudo R2	**.55**						**.78**					

Note: nl = variable in natural logs
* is significant at 10%, ** is significant at 5%.

The first set of equations for mobility, stock densities and land allocation include only total households and heterogeneity in livestock holdings as regressors capturing the extent of non-cooperation. The total household variable is not significant in any of the equations, and heterogeneity in livestock holding is only significant in the stock density equation. Alternatively, the second set of equations includes the costs of cooperation indices. These equations uniformly exhibit better goodness-of-fit measures and p-values on individual coefficients are consistently higher. In the following, then, we discuss results for this second specification only.

Looking first at the climatic variables, we note that the coefficient of variation of rainfall does indeed have nonlinear relationship with stock densities, but opposite to the impact that would be consistent with hypotheses stemming from new range ecology and/or herd accumulation models. In sample communities, higher variability initially leads to greater stock densities but the impact becomes negative for coefficients greater than about .27. If it were rational to accumulate herds in anticipation of a drought, particularly in areas where long-term forage productivity is posited to be relatively unaffected by stock densities, then we would expect higher stock densities particularly in high variability areas, *ceteris paribus*. Our data, however, does not support this hypothesis. Rather, it appears that gains from shifting more heavily into livestock as variability increases are eventually outweighed by risk externalities generated from the use of common-pool pastures as rainfall variability increases still further. Rainfall variability has a similar impact on mobility; mobility at first increases and then decreases with increases in variability. In the reduced form model, these variables should be picking up the effect of stock densities on mobility; higher stock densities lead to greater mobility, as predicted. Recent rainfall has a significant negative impact on mobility whereas average rainfall has no impact. Interestingly, none of the climate variables has a statistically significant impact on cropland.

Consider next the cooperation variables, captured in the cost of cooperation indices and heterogeneity in livestock holdings. The first index of cooperation costs has a significant and positive impact on stock densities and on mobility. However, whereas the second index also has a significant and positive coefficient in the stock density equation, the coefficient is negative and significant in the mobility equation. The first cost index appears to capture the indirect effect of higher stock densities on mobility, whereas the second index appears to capture the direct negative effect of increased costs of cooperation on mobility. Heterogeneity in livestock holdings also has a differential impact on "cooperation" as predicted. The coefficient is positive and significant in both stock density and mobility equations. We hypothesized that livestock heterogeneity would contribute to overgrazing as captured in the stock density equations, but would also foster mobility. Finally, we note that only the second cost index has a significant impact on land allocated to crops. However, the negative coefficient is opposite to that hypothesized, since both direct and indirect impacts are hypothesized to be positive. The second index has a relatively high scoring coefficient on rainy season in-migration; thus, claims by outsiders, particularly to community resources during the cropping season, appears to limit land allocated to crops. Unfortunately, given the dataset, we cannot explore this hypothesis further.

With respect to community characteristics and infrastructure, we note that the coefficient on household density is significant in all three equations. Household density has a positive impact on stock densities and mobility, but a negative impact on land allocated to crops. Though the usual presumption is that increasing population density will increase pressure to open up marginal lands to cultivation, that does not appear to be the case in the communities in this particular region in Niger. This is all the more surprising given that government and NGO technical projects tend to support intensification of cropping activities. As can be seen in Fig. 3 below, however, there is a clear negative relationship between cropland and household density[7]; a relationship that remains strong in the multivariate analysis. If increasing household density does indeed capture intensification, the intensification in this system appears to be occurring with respect to livestock, inducing greater stock densities, increased mobility, and less land allocated to crops.

The stock of agricultural assets per household in the community has a significant and positive impact on cropland, but no impact on either stock densities or mobility. Whether the ethnic majority is traditionally pastoralist surprisingly has no impact on mobility, or on stock densities or cropland. Range quality has a positive impact on mobility and land allocated to crops, but the coefficient on stock densities is positive but not significant. Finally, relative livestock: millet prices have a significant and positive impact on mobility; this should be an indirect impact through higher stock densities. However, there is no statistically significant impact of relative prices on either stock densities or cropland. Distance to market has a strong negative impact on stock densities.

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[7] Plotting percent of land in crops against total households gives a similar result.

6. CONCLUSIONS

There are a number of conclusions to be drawn from the above analysis. First, stock densities in sample communities do not support a conclusion of universal over-exploitation of pastures, as would be the case if the "tragedy of the commons" argument held. However, there is a wide range of stock densities and herd mobility observed. Second, even in the universal absence of formal "rules" or regulations regarding stocking rates on common pastures or herd mobility, factors associated with the costs of achieving collective action to secure cooperation at the community level do impact decisions on stocking rates and on mobility. Though difficult to address directly through policy measures, the results reinforce the notion that devolution of natural resource management must consider factors that influence the costs of cooperation. For instance, results indicate that heterogeneity in ethnicity and wealth may make cooperation more costly, and programs that promote collective action should take into account the higher costs of achieving collective action in these villages. Federated structures, graduated schedules of benefits, taxes, and/or fines, or sub-group formation has improved collective action in other countries/activities, though this analysis cannot provide any further information on the specific management structures.

Also, we have shown that rainfall variability has an inverted-U shaped relationship with stock densities and mobility, though no impact on percent of land allocated to crops. Results for stock densities are consistent with results from Kamara et al. (2001) from a similar study undertaken in Ethiopia, where rainfall variability also has a negative impact on stock densities precisely in the high variability environments. This result is important, because many drought mitigation and preparedness measures are predicated on the belief that policy measures that offset the impact of rainfall variability on livestock production will lead to lower stock densities. Our results do not support this belief; rather, it is likely that stock densities would increase in response to measures directly aimed at reducing the impact of poor rainfall on output, at least in regions characterized by high rainfall variability. Complimentary policies need to be developed that mitigate the impacts of drought and also increase off-take.

REFERENCES

Agnew, C. T. 1995. Desertification, drought and the development in the Sahel. In *People and environment in Africa*, ed. Binns, T. Chichester, UK: Wiley.

Alesina, A. and E. La Ferrara. 1999. *Participation in heterogeneous communities*. Working Paper 7155. Cambridge, Mass: National Bureau of Economic Research.

Arrignon. 1987. *Agro-écologie des Zones arides et sub-humides*. Paris: G.-P. Maisonneuve & Larose-Agence de Coopération Culturelle et Technique.

Baland, J-M. and J-P. Platteau.1997. Wealth inequality and efficiency in the commons, part I: The unregulated case. *Oxford Economic Papers* 49: 451-482. Oxford: Oxford University Press.

Baland, J-M. and, J.-P. Plateau. 1996. *Halting degradation of natural resources: Is there a role for rural communities?* New York, USA and Oxford: Food and Agricultural Organization and Clarendon Press.

Banouin, M., C. Gueye, I. Soumana, M.Ali and P. Jouve. 1996. Péjorations climatiques et évolutions des pratiquesde transhumance en zone agro-pastorale sahélienne, le cas de l'arrondissement de Mayahi, au Niger. In *Gestion des terroirs et des ressources naturelles au Sahel*, ed. P. Jouve, proceedings of a workshop, Montpellier, France, 2-3 April, CNÉARC.

Behnke, R.H., I. Scoones, and C. Kerven. 1993. *Range ecology at disequilibrium: New models of natural variability and pastoral adaptation in African Savannas.* London: Overseas Development Institute.

Berkes, F. and C. Folke. 1998. *Linking social and ecological systems: Management practices and social mechanisms for building resilience*. Cambridge: Cambridge University Press.

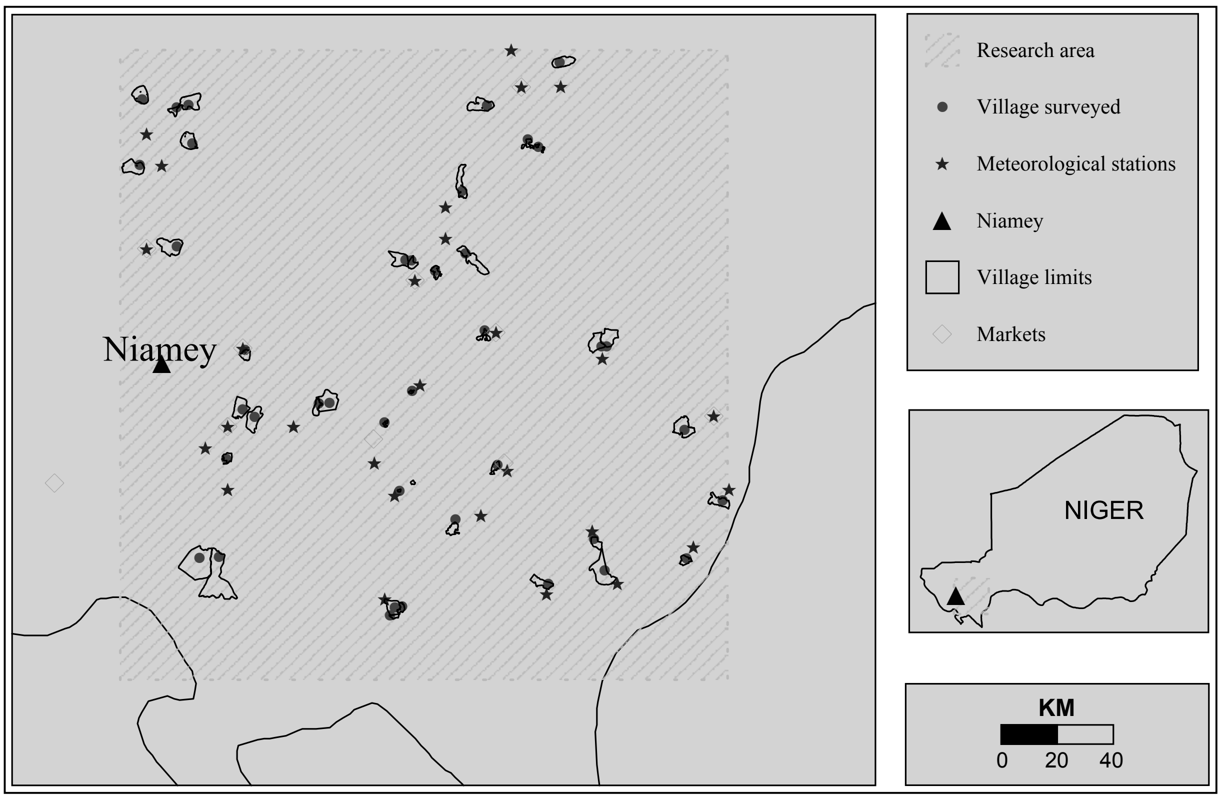
Boserup, E. 1965. *The conditions of agricultural growth: The economics of Agrarian change under pressure*, 4th edition. London: George Allen & Unwin.

Cleaver, K. M. and G. A. Schreiber. 1994. *Reversing the spiral. The population, agriculture, and environment nexus in sub-saharan Africa*. Washington, D.C.: World Bank.

Colin de Verdière, P. 1995. Etude comparée de trois systèmes agropastoraux dans la région de Filingue-Niger-. PhD.diss, Institute fur Tierproduktion in den Tropen und Subtropen, Universität Hohenheim, Stuttgart.

Figure 1--Map of research areas

Map showing the limits of the survey area, the location of the villages surveyed and their limits, the location of the meteorological stations, and the location of the markets surveyed.



Dasgupta, P. and G.M. Heal. 1979. *Economic theory and exhaustible resources*. Cambridge: Cambridge University Press.

de Janvry, A., N. McCarthy and E. Sadoulet. 1998. Endogenous provision and cooperation on the commons. *American Journal of Agricultural Economics*, 80: 658-664.

de Leeuw,P.N. and Tothill, J.C. 1993. The concept of rangeland carrying capacity in sub-saharan Africa: Myth or reality. In *Range ecology at disequilibrium: New models of natural variability and pastoral adaptation in African Savannas,* ed. Behnke, R., I. Scoones and C. Kerven. London: Overseas Development Institute.

Ellis, J.E., K. Galvin, J.T. McCabe, and D.M. Swift.1987. *Pastoralism and drought in Turkana district, Kenya.* Report prepared for NORAD, Nairobi, Kenya.

Fafchamps, M. 1998. The tragedy of the commons, livestock cycles and sustainability. *Journal of African Economies* 7(3): 384-423.

Fleuret, A. 1986. Indigenous responses to drought in sub-Saharan Africa. *Disasters* 10 (3): 224-228.

Freudenberger Schoonmaker, M. and K. Schoonmaker Freudenberger. 1993. *Pastoralism in peril: Pressures on grazing land in Senegal*. Pastoral Land Tenure Series no.4. London: International Institute for Environment and Development.

Gado, B. A. 1996. Le code rural au Niger : une réforme prometteuse, une application difficile. In *Démocratie, enjeux fonciers et pratiques locales en Afrique*, ed. P. Mathieu, P.-J. Laurent and J.-C. Wilame. Bruxelles; Paris: Institut Africain-CEDAF; Harmattan.

Gavian, S. and M. Fafchamps. 1996. Land tenure and allocative efficiency in Niger. *American Journal of Agricultural Economics* 78 (2): 460-471.

Grégoire, E. 1982. Un système de production agro-pastoral en crise: Le terroir de Gourjae (Niger). In *Enjeux fonciers en Afrique noire*, ed. E. Le Bris, E. Le Roy and F. Leimdorfer. Paris; Bondy: Karthala; ORSTOM.

Johnson, R. and G. Libecap. 1982. Contracting problems and regulation: The case of the fishery. *American Economic Review* 72: 1005-1022.

Kirk, M. and Ngaido, T. 2001. Collective action, property rights and devolution of rangeland management. In *Collective action, property rights and devolution of natural resource management: Exchange of knowledge and implications for policy*. Ruth Meinzen-Dick, Anna Knox, and Monica Di Gregorio, eds.

Proceedings of the International Conference held from 21 - 25 June, 1999 in Puerto Azul, The Philippines. Feldafing: German Foundation for International Development (DSE).

Kamara, A., N. McCarthy and M. Kirk 2001. The effect of environmental variability on livestock and land-use management: The Borana Plateau, Southern Ethiopia. *Journal of African Economies.* Submitted.

Le Bris, E. 1982. Le statut du foncier dans les études de terroirs menées par les géographes en l'Afrique de l'Ouest', in *Enjeux Fonciers en Afrique Noire*, ed. Le Bris, E., E. Le Roy and F, Leimdorfer. Paris: Bondy, Karthala: ORSTOM.

Livingstone, I. 1991. Livestock management and "overgrazing" among pastoralists. *Ambio* 20 (2): 80-85.

Marty, A. 1996. La gestion des terroirs et les éleveurs: un outil d'exclusion ou de négociation? In *Gestion des terroirs et des ressources naturelles au Sahel*, ed. P. Jouve, proceedings of a a workshop, Montpellier, France , 2-3 April, 1996, CNÉARC.

McCarthy, N., E. Sadoulet and A. de Janvry. 2001. Common pool resource appropriation under costly cooperation'. *Journal of Environmental Economics and Management*, 42 (3): 297-309.

McCarthy, N. 1999. An economic analysis of the effects of production risk on the use and management of common-pool rangelands', in *Property Rights, Risk and Livestock Development in Africa*, ed. N. McCarthy, B. Swallow, M. Kirk and P. Hazell. Nairobi and Washington, D.C.: International Livestock Research Institute and International Food Policy Research Institute.

Ngaido, Tidiane. 1993. *Implementing the rural code: Perceptions and expectations of rural Niger.* Discussion Paper No. 7, Land Tenure Center. Madison, WI, U.S.A.: University of Wisconsin.

Ngaido, T. 1995. Making laws and building institutions in the Sahel: The case of Niger. *Entwicklung und Ländlicher Raum* 6: 19-22.

Niamir-Fuller, M. ed. 1999. *Managing mobility in African rangelands: The legitimization of transhumanc.* London; Rome: Intermediate Technology Publications; FAO; Beijer International Institute of Ecological Economics.

Nicholson, M. J. and M. H. Butterworth. 1986. *A guide to condition scoring of zebu cattle.* Addis Ababa, Ethiopia: International Livestock Center for Africa.

Oakerson, R. J. 1992. Analyzing the commons: A framework. In *Making the commons work. Theory, practice and policy*. ed. Daniel W. Bromley. San Francisco, CA, U.S.A.: ICS Press.

Ostrom.E. 1990. *Governing the commons: The evolution of institutions for collective action.* Cambridge and New York: Cambridge University Press.

Painter, T., J. Sumberg and T. Price. 1994. Your terroir and my "action space": Implications of differentiation, mobility and diversification for the Approche Terroir in Sahelian West Africa. *Africa* 64 (1):447-464.

Raynault, C. 1988. Aspects of the problem of land concentration in Niger. In *Land and society in contemporary Africa*, ed. R. E. Downs and S. P. Reyna. Hanover: University Press of New England.

Ruttan, L. 2000. Conservation and wealth asymmetries among East African pastoralists. Presented at "Constituting the Commons," the eighth annual conference of the International Association for the Study of Common Property. May 31-June 4, Bloomington, Indiana, USA.

Sandler, T. and F.A. Sterbenz. 1990. Harvest uncertainty and the tragedy of the commons. *Journal of Environmental Economic and Management* 18 (2): 155-167.

Schlager, Edella and Elinor Ostrom. 1992. Property-rights regimes and natural resources: A conceptual analysis. *Land Economics* 68 (3): 249-262.

Secrétariat Permanent. 1993. Ordonance 93-105 Principes d'orientation du Code Rural, Comité National du Code Rural', Ministère de l'Agriculture et de l'Élevage, République du Niger, Niamey, Niger.

Secrétariat Permanent. 1997. Recueil de textes complémentaires à l'ordonnance 93-105 portant principes d'orientation du Code Rural', Comité National du Code Rural, Ministère de l'Agriculture et de l'Élevage, République du Niger, Niamey, Niger.

Starr, M. A. 1987. Risk, environmental variability and drought. Induced impoverishment: The pastoral economy of Central Niger. *Africa* 57 (1): 29-50.

Swallow, B. 1994. *The role of mobility within the risk management strategies of pastoralists and agro-pastoralists.* Gatekeeper Series No.47. London: International Institute for Environment and Development.

Thompson, G. and P. N. Wilson. 1994. Common property as an institutional response to environmental variability. *Contemporary Economic Policy* 12: 10-21.

van den Brink, R., D. Bromley and J.-P. Chavas. 1995. The economics of Cain and Abel: Agropastoral property rights in the Sahel. *Journal of Development Studies* 31 (3): 373-399.

Figure 2--Schematic description of the rainy season pastoral action space

The different spatial sub units are separated by the discontinued line. The first sub unit consists of the village rangeland (A). The second unit consists of rangeland nearby (B) under the jurisdiction of nearby villages or under the jurisdiction of the district chief. Access to this rangeland is never negotiated. A third sub unit consists of rangelands that are 20 to 50 km from the village (C) and that are used during the late dry season when rain onset in the village is late. Access to this rangeland is sometimes negotiated (it used to be strictly negotiated). Finally there are the pastures reached during transhumance (100 to 200 km away) (D) for which there is no negotiation for access. These sub units can be directly connected allowing a smooth passage from one to the other, or, more often, they are connected by transhumance corridors (E).

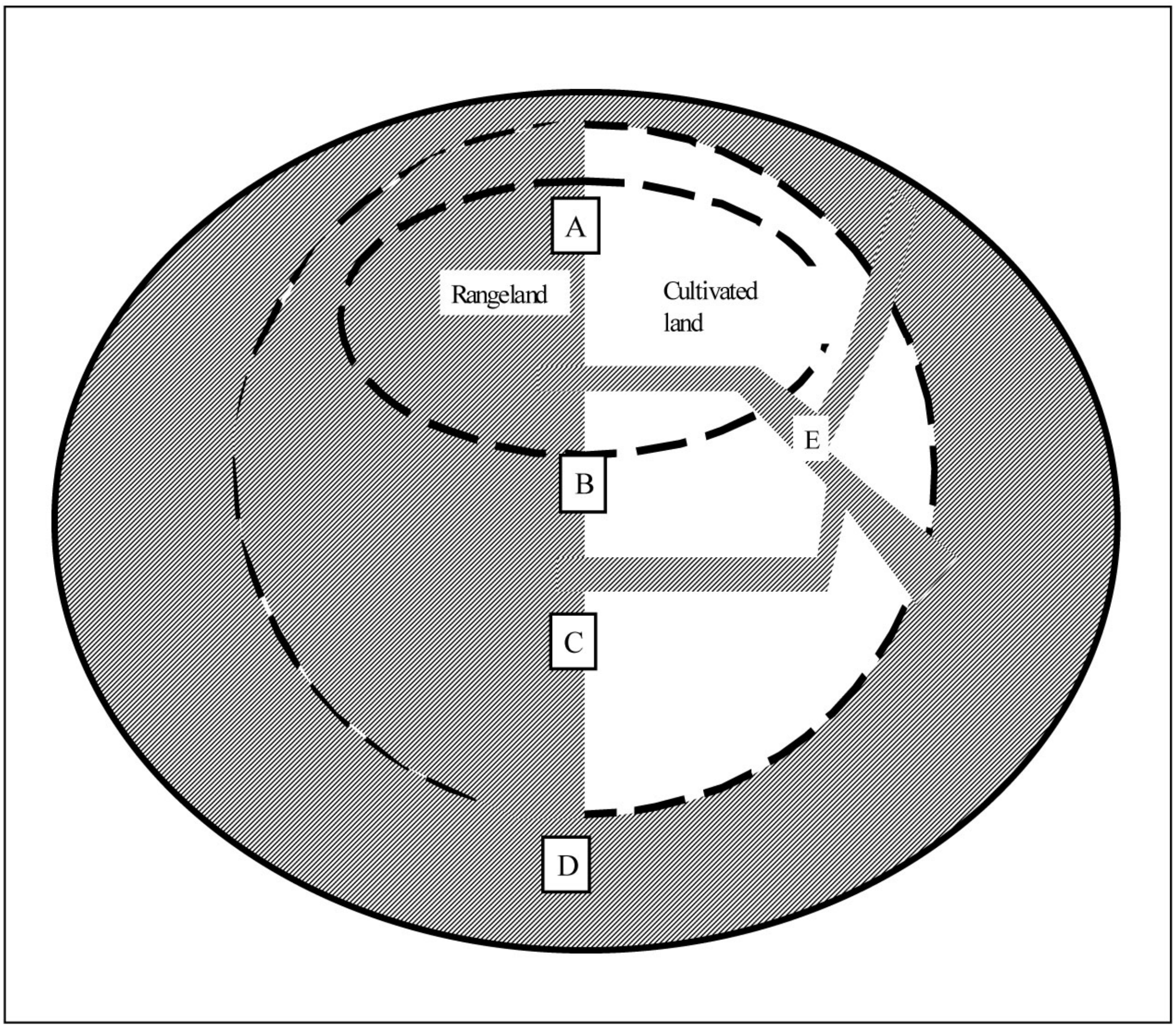
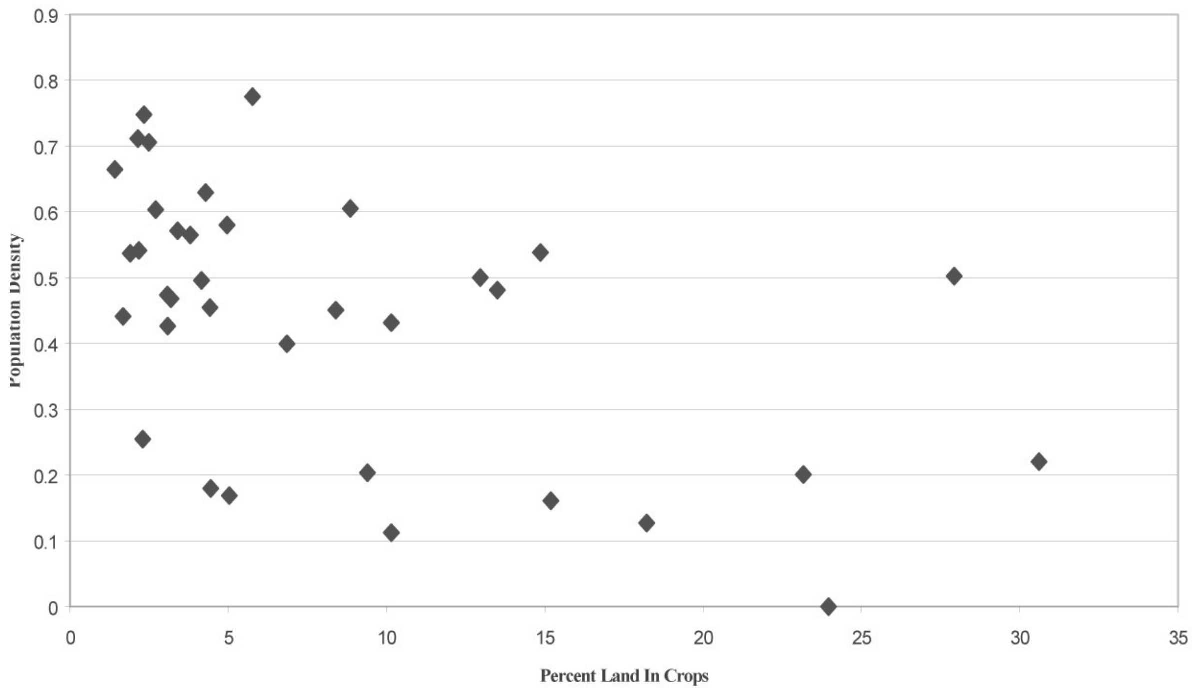


Figure 3--Percent land allocated to crops as a function of household densities



Appendix 1--Community surveys and descriptive statistics

A stratified sample of forty villages was determined, where the stratification criteria were average annual rainfall and rainfall variability. Because of topological characteristics, it was impossible to adequately measure total land area in three communities and/or to complete the range quality assessments.

In order to minimize soil variations, all villages were chosen on the edge of the continental shield between 12°30’ and 14°30’ north, and between the second and the fourth eastern meridians. Villages were selected near meteorological stations for which rainfall data were available from 1988 to 1996. Seventeen meteorological stations had all monthly data for the period considered, while eleven needed the interpolation of a minority of their monthly data. When necessary, monthly rainfall were interpolated using the iterative polygon method. A map showing the survey area is presented in Figure 1. This data was augmented with rainfall data obtained from the University of Delaware dataset for Africa, spanning 1950 – 1999. While the average monthly and annual rainfall figures were quite similar for both datasets, the coefficient of variation was greater for data collected at rainfall stations, though this data series is of shorter time duration[8].

Mobility. Of the forty villages surveyed, a majority (25) had a part of their livestock away from their village land during some part of the rainy season, and a minority engaged in transhumance during the dry season (9). Community members have access to a wide range of pastures of the “outside” world. This is at the cost of labor to

[8] The longer time series data is generated using spatial interpolation techniques, and these techniques tend to dampen measures of spatial variability.

guard and herd the animals on outside pastures, and in some cases, the cost of increased risks of livestock losses.

Short term (less than one month) movements to pastures less than 50 kilometers away occurred generally (and not necessarily every year) towards the end of the dry season. Access to these pastures can be negotiated or not. In our sample, negotiations occurred in cases where the destination area was under the jurisdiction of a traditional Fulani encampment area. The most important destinations for long term (lasting four months or longer) transhumance during the rainy season are pastures in Northern Niger and, more recently, southern Benin. Informants across different Fulani encampments agreed that transhumance to Benin dated from the 1982-1983 drought and that, while pasture quality is inferior, pasture quantity and livestock safety are better in Benin.

However, in our estimated equations, we did not distinguish between long and short distance mobility. Instead, we set mobility equal to the proportion of total herds migrating during the dry season and the rainy season; weighting the rainy season by 5/12 and the dry season by 7/12 to arrive at total proportion of mobility through the year.

<u>Participatory mapping.</u> In each village, community level interviews with key informants (village chief and their advisors) were conducted. The participatory mapping consisted of the progressive drawing in the sand, by the community members, of the village land including the location of fields, pastures, water, areas of particular geographical interest etc. While the different elements of the map were identified, questions were raised regarding their use and eventually their management. The participatory mapping contributed to the building of a healthy relationship between

investigators and interviewees, as well as to a common understanding of the research theme and objectives.

Resource assessment. A precise determination of the village land boundaries and an assessment of the village's grazing resources was then conducted. The preparation of this field survey consisted of the preliminary identification of the different geographical units of the village land using a 1/50,000 base map.

When physical presence on the village land boundaries was possible, their location was recorded (under digital format) using a twelve-channel Global Positioning System. The boundaries were also recorded by drawing them on an overlay to the 1/50,000 map. When physical presence on the boundaries was not possible due to steep hills or ravines, the base map was used to interpret the information given by the village chief before drawing the borders on the overlay.

The resource assessment consisted of a survey conducted for each of the geographical units that were identified during the field survey preparation. For each geographical unit, the following information was geo-referenced and was visually estimated: proportion of fallow, bush, cultivated and barren land; millet density on cultivated fields; species composition (three dominant species) for the herbaceous layer and species composition for the tree layer (three dominant species); and level of grazing on the pastures. The maps were digitized and stored using a Geographic Information System. For a subset of villages, the mapping exercise in the fields is supplemented by a visual interpretation of satellite images (Spot multi spectral). This information was used to generate total land area, and the proportion of land dedicated to pastures and crops.

The information on species composition and density were used to generate a range quality index for each of the geographical units identified on the village land, using a score of 1 to 5. Range quality for each village is computed using the following formula, where i is a pasture score and A_i the proportion of the area available for pasture with the score equal to i.

$$RQ = \sum_{i=1} iA_i$$

Gathering of socioeconomic data. Once the field survey was completed, group interviews were conducted to gather socioeconomic data. Data collected included number of cattle, goats and sheep (usually by sub-community units), average and maximum holdings of each livestock species, the number of households without cattle, average and maximum cropland holdings, ethnic composition and number of languages spoken within the community, use of the community pastures by non-community members in the dry and in the rainy season, and the proportion of community members who had at least one member who migrated for wage work. Additional information was collected on basic infrastructure, and also on the stock of crop-specific assets, including ploughs, carts, storage facilities, etc. Also, there was little information on the costs of mobility (in communities that relied on hired herders), but this information was only available for a small subset of communities. We thus used information on whether community members come from a tribe recognized as being traditionally pastoralist, in order to capture accumulated knowledge, and the percent of households still considered "pastoralist" by community members, to capture capacity to collect current information regarding conditions on outside pastures.

Land Allocation. Using the results of the surveys one can schematically represent the pastoral action space of a community, as depicted in Figure 2. First there is the village land corresponding to the French concept of "terroir foncier" (Le Bris 1982). The land encompassed in the "terroir foncier" is under the jurisdiction of the village chief. Certain decisions regarding land use are taken at the individual level (short term fallow), but allocating use rights to cropland is undertaken at the level of the village chief. The quantity of rangeland available on the "terroir foncier" will therefore be the result of decisions by the chief. In our model, we assume that land allocation will be a function of the sum of individual incentives to privately appropriate crop land, which are themselves dependent on stock densities on the common pastures. Cooperation is hypothesized to offset the tendency to over-stock and under-provide common pastures. In the field, this means that we hypothesize that land allocation decisions by the chief will be a function of cooperative capacity, and the costliness of making and enforcing decisions. And, the costs of cooperation are a function of individual incentives to abide by community-level decisions. Thus, we hypothesize that observed land allocation patterns will be affected by these variables, mediated through the institution of the chief.

Livestock price survey. A separate livestock price survey was conducted in 10 markets that were identified during the community surveys. Each market was visited 6 times during a twelve-week period. Small ruminants were weighed. Girth measurement was taken from cattle in order to estimate their liveweight; the physical condition of cattle was scored using the method explained in Nicholson and Butterworth (1986). Because animals are sold standing, we estimated a per unit value, using girth, physical condition score, age, and date of sale. This estimation was used to generate a price per kg. for a 3

½ year old male bull of quality 2.5, which is the price used in the estimations below. We chose to use cattle as representative since the price information was the richest, cattle represent the majority of tropical livestock units in all but one community, and all livestock prices were highly correlated. Millet prices per kg were also collected and used to generate the relative price of livestock to millet.

LIST OF CAPRi WORKING PAPERS

01 Property Rights, Collective Action and Technologies for Natural Resource Management: A Conceptual Framework, by Anna Knox, Ruth Meinzen-Dick, and Peter Hazell, October 1998.

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23 *International Conference on Policy and Institutional Options for the Management of Rangelands in Dry Areas*, Tidiane Ngaido, Nancy McCarthy, and Monica Di Gregorio, January 2002.