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THE IMPACT OF COOPERATION ON STOCK DENSITIES AND MOBILITY: A CASE STUDY FROM NIGER

by

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Introduction

Rainfall variation is often identified as the major environmental risk faced by agro-pastoralists (e.g., Swallow 1994). In the case of Niger, Sivakumar (1989) and Sivakumar et al. (1993) present detailed analysis of climatic characteristics and their pattern over time; key results include documentation of the high relative rainfall variability and recently increased frequency of droughts. In such environments, households must adopt mechanisms to manage the variability in agricultural activities (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, as it enables herders to both improve the mean output as well as decrease the output fluctuations associated with both spatial and temporal variability in rainfall (e.g. Fleuret 1986; Painter et al. 1992; Swallow 1994; van den Brink et al. 1995). Broadly speaking, land tenure in this region consists of a mix of quasi-private, and "common"[3] property, allowing for both fixed agricultural production and mobile cattle raising[4]. Nevertheless, the combination of population increase, the consistent low rainfall for nearly two decades in the 1970's and 1980's, and a changing institutional environment have all contributed to increasing stress on land tenure systems.

Since1993, the government of Niger has begun implementing a new rural code that attempts to redefine the access, use, and management of natural resources in Niger (Secrétariat Permanent 1993, 1997). Successful implementation requires that the importance of environmental variability and the use of land for both agricultural and pastoral activities contribute to a new definition of land tenure in Niger. The purpose of this paper is therefore twofold: to contribute, using quantitative methods, to the common-

[3] It is recognized that though various individuals or groups recognize shared claims to various resources, they rarely "fit" the oft-used definition of common property, which generally assumes that both who is a "user" and the boundaries of the resource are well-defined. Nonetheless, common property comes closest to describing the actual situation; it is generally definitely neither private nor open access.
[4] A general description of Niger and of the work area can be found in Williams et al., this conference

pool rangeland/ mobility debate and to contribute to a better understanding of the situation in Niger—a prerequisite for developing changes in the land tenure system that benefits all users.

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.

Property Rights and Agricultural Production in Niger

Land tenure in Niger is under stress. A first source of stress is the changing natural and demographic environments, while the second source of stress comes from political changes. We consider these in turn below, after describing the historical development of property rights and land tenure.

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 is an instance of deep transformation imposed by the colonial power. Nevertheless, the impact of the French rule in Niger on agricultural land tenure does not appear to have been very important, particularly in the more arid regions with which we are concerned. This can be explained by the fact that Niger, because of its unfavourable environmental conditions, was mainly seen as a reservoir for labour. 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, canton chiefs and their lineage. Chiefs could allocate land and receive tithe 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 (Ngaido, 1995). It must be noted however that a majority of tenants and use-right rights 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 (Lund 1996). 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.

When considering rangeland, it must be noted that, since 1959, Niger has been divided into two areas; one being where agricultural activities are theoretically prohibited, the “zone de modernization pastorale”, the other, where agricultural and pastoral activities are to coexist, the “zone agropastorale”. Most of the following paragraphs concern the “zone agropastorale”, which encompasses all of the geographical area where the present research has been conducted.

Rangeland 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 it was 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). It must be stressed that at the present time rangeland is largely under the control of groups with a strong agricultural tradition.

Recently, concerns have 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. Although it may be early to assess the impact of the "terroir" approach on land tenure, some elements need to be highlighted here. 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 contribute to a further transformation from 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 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 continuence – 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[5]. 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, one might say that it is characterized by the existence of traditional tenure arrangements that are facing challenges posed by population increase, by unfavorable changes in climate, and by the changing political environment. There seems *a priori* to be a shift from a tenure system geared toward an equilibrium between pastoral and agricultural activities to a system geared toward agricultural activities. This is mainly attributed to increasing relative and absolute arable land scarcity combined with a growing importance of agriculturalists in the local political sphere. Following the droughts in 1973-1974 and in 1981-1982, pastoralists lost most of their cattle through death or sale to other segments of the population (White 1987; Habou and Danguioua 1991). Marginalization of pastoralists in terms of land tenure occurred, therefore, in particularly difficult times.

Model Development

In order to develop the empirical model, we begin by considering theoretical arguments regarding property rights and risk – "risk" in our case being captured by spatial and temporal variation in rainfall. The system described above is quite complex; any model

[5] See Cleaver and Schreiber 1994, 21-24; and for detailed Nigerien case studies see Colin de Verdière, 1995 and Banouin, et al. 1996.

must incorporate both risk-averse behaviour, the role of livestock mobility, and the potential of community members to manage common rangelands and to determine the best use of land (allocated between pastures or agricultural land).

Standard non-cooperative game models of use-rates of common rangelands show that use rates are greater on the commons than would be the case under the social optimum, and that the degree of over-use increases in the number of members (this is the basis of the standard argument regarding the “tragedy of the commons” (Hardin, 1968)). However, there is now ample evidence that complete non-cooperation need not be the only outcome; there are many empirical examples where community members do in fact manage natural resources and provide public goods, with varying degrees of success (c.f. case studies provided in Ostrom, 1992; Berkes and Folkes, 1998; and Baland & Plateau, 1996 – by no means an exhaustive list). McCarthy et al. (2001) develop a theoretical model of costly cooperation, where the degree of cooperation reached is a function of the net gains to cooperation; themselves a positive function of profitability (higher output prices, lower input costs, the underlying technical productivity of the resource). The number of members at first increases gains from cooperation, but at some level, increased members leads to lower gains. The more traditional variables associated with cooperation – heterogeneity, well-defined users and well-defined boundaries of the resource, “social capital” such as trust etc., also affect the degree of cooperation reached. Nonetheless, there remains a great deal of debate in the literature regarding the impact of almost any variable on cooperation; we carefully outline our hypotheses regarding the impact below, where we discuss variables used in the estimation.

Much of the confusion in the literature on community-level management stems from the fact that there are many potential activities over which a group can cooperate – and the impact of various factors may differ depending on the particular activity under study (Sandler, 1996). In the preceding paragraph, we were concerned with use-rates on a common-pool resource. Though there is no dominant strategy when modeled as a non-cooperative game, at each possible point of cooperation, the associated incentives reduce to a prisoner's dilemma. These incentives form the basis of the marginal costs of cooperation in McCarthy et al. (2001) cited above. However, community members may also cooperate over the extent of mobility; since mobility reduces pressures on community pastures. As modeled in a paper by Dhardan (1999), a simplified model of the choice to engage in mobility takes the form of a "chicken" game. Because mobility is costly, each person wants the others to move, but to remain at home themselves. However, the gains from moving even when others remain at home outweigh the benefits of all staying at home[6], so that eventually at least some members will engage in mobility.

We can now address the critical role of heterogeneity. When the activity to be regulated is use of the common pasture, we hypothesize that heterogeneity will negatively affect the degree of cooperation, and thus positively affect the stock density. Given the "prisoner's dilemma"-type incentives, it is never optimal for one member to unilaterally reduce stock-days; and, the greater the degree of heterogeneity, the less likely it is that there will exist possible cooperative agreements that leave all members better off[7]. However, with economies of scale in mobility, it may well be that larger herd owners optimally choose mobility, irrespective of the decisions of smaller herd owners. In this case, heterogeneity may in fact be associated with greater mobility and thus less pressure on home resources.

The final decision affected by the degree of cooperation is the allocation of land between usufruct (private) cultivation by individual households and common – or open access -- pastures. To the extent that community pastures are restricted to community members, the pasture land would be considered typical common property, with fixed

[6] This assumption is critical. If the costs of mobility are sufficiently high, then the game can be represented as a prisoner's dilemma. On the other hand, with very low costs of mobility, the game will degenerate to one where the "social" optimum and the non-cooperative outcomes are the same – where all members engage in mobility.

[7] We note that for heterogeneity to lead to a situation where no cooperative agreement leaves all members better off requires that side-payments (from the gainers to the losers) are not allowed.

membership. However, in most cases, pasture and cropland in fallow are also accessible to non-community members to some degree, as discussed above. The decisions by community members on stock-days plus the extent to which community pastures are accessed by outsiders determine the actual use-rates and therefore the marginal productivity of land allocated to pastures. This resulting productivity will be equated to that arising from cultivation, thereby determining land allocation. Thus, the degree of cooperation reached in a community affects how much land will be left in pastures, and how much will be dedicated to cultivation. In all of the above cases, the extent to which the resource is over-exploited or under-allocated will be a function of the number of members. Cooperation is thus hypothesized to offset – though not necessarily perfectly – non-optimal exploitation of community resources.

Turning now to climatic variability, the hypothesized impact of this type of risk on herd sizes is a source of contention in the wider literature. On the one hand, researchers have posited that herders will (attempt) to hold onto more livestock in high variability environments; the main reason being that larger herd sizes going into a drought is thought to mean a greater probability of coming out of the drought with some animals (Livingstone, 1996; Fafchamps, 1998; Niamir-Fuller, 1999). This argument, while dynamic, 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 signficantly greater when the pasture is not perfectly managed. There is scant empirical evidence; though Ellis et al. (1987) show that mortality during the 1984-85 drought in the Turkana region of Kenya was higher in areas with higher stock densities in the period preceeding the drought, which undermines the reason for holding onto more animals going into a drought.

The second line of thought stems from examining the impact of rainfall variability on the outcomes of non-cooperative games. Sandler and Sterbenz (1992) and McCarthy (2001) show that increased variability will lead to lower stock densities under any property rights regime; the reduction will be greater under perfect cooperation vis-à-vis non-cooperation. One of the main hypotheses to be tested below, then, is the sign of the impact of rainfall variability on stock densities.

Regarding mobility, we hypothesize that rainfall variability will have a positive effect – the value of moving will be higher in regions experiencing erratic rainfall both spatially and temporally (van den Brink et al., 1995). Finally, to the extent that livestock is less variable than crops, but that both co-vary positively, 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 multivariate risks – the sign is actually ambiguous (McCarthy, 1999). This arises primarily because of the additional risk externality generated from the use of common pastures when these pastures are imperfectly managed; externalities that do not arise from cropping. Attempts to avoid these additional externalities may lead to the case where a higher fraction of land is allocated to crops rather than vice versa. Because of the relatively low mean rainfall, however, we hypothesize that the impact of rainfall variability on land allocated to crops will be negative.

Incorporating the above information leads to the following system of equations:

SD=*f*(Mob, CoV, RQ, Plm, Di, Mem, IC)

Mob=*f*(SD, CoV, Mem, IC, CostM)

L-Crop=f(SD, Mob, Plm, Rain, CoV, Mem, IC)

SD = the actual stocking rate on the village rangeland,

Mob = the percent of the village herd migrating to outside pastures in the rainy season

L-Crop = percent village land allocated to crops

RQ = range quality index

Plm = relative price of livestock to millet

Di = distance to the nearest regional livestock market

Mem = total number of households

IC = an index of factors associated with ability to make and enforce cooperative agreements

CostM = cost of mobility

CoV = Coefficient of Variation of Rainfall

Rain = Mean annual rainfall

In addition to rainfall variability and mobility, community level stock densities will be a positive function of range quality and the number of members, and a negative function of the cooperation. As developed above, mobility is a function of stock densities, rainfall variability, number of members and cooperation; and also a function of the costs of mobility. It is posited that land allocated to crops will be a function of average rainfall as well as other variables previously mentioned; average rainfall has a similar land productivity interpretation as does range quality in the stock density equations. In the case of extensive crop-livestock interaction, as with study villages, the inter-relationship should be captured by the relative livestock:millet price.

Community Surveys and Descriptive Statistics

A stratified sample of forty villages was selected; the stratification criteria were average annual rainfall and rainfall variability. 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 1990 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 (see table 1). When necessary, monthly rainfall were interpolated using the iterative polygon method as described in Morel (1992, pgs. 22-23). A map showing the survey area is presented in Figure 1.

Participatory mapping

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, area 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. The next step consisted of a field survey conducted with the village chief and/or his representative.

Resource assessment

Following the participatory mapping exercise a precise determination of the village land boundaries and an assessment of the village's grazing resources was 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 was 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).

Gathering of socioeconomic data

Once the field survey was completed, group interviews were conducted to gather socioeconomic data. Some descriptive statistics of the sample communities surveyed are presented in Tables 2 and 3. The community surveys in their totality took 1.5 to 4 days per village.

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).

Property Rights

Regarding agricultural land, the pattern described earlier applied to all villages surveyed. Regarding rangeland, the situation was a bit more complex. Interviewees in 25 villages reported that the pastures of the village were not used by neighbors during either the dry or rainy seasons. The only outsiders that were reported in these villages were transhumant herders during the early and late dry season. In the villages where rainy season pastures were actually used by neighbors, their contribution to the total stocking rate rarely exceeded 10 %.

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. Using the results of the surveys one can schematically represent the pastoral action space of a community (see 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. Decisions regarding land use are taken at the individual level (short term fallow) and at the level of the village chief (use of long term fallow). The quantity of rangeland available on the "terroir foncier" will therefore be the result of decisions at the household and the community levels. Outside the village land, village members have access to a wide range of pastures of the "outside" world. This, of course, is at the cost of labor to guard and herd the animals on outside pastures, and at in some cases, the cost of increased risks of livestock losses.

Daily movements to pasture shared with other villages in the direct vicinity occur generally during the rainy season. These pastures were often situated on plateaus bordering the village. These daily movements are justified by the need to have the animals graze in a place where they do not interfere with agricultural production. These pastures can be under the jurisdiction of a nearby village or under the jurisdiction of the "chef de canton" (district chief). No communities reported negotiating access to these pastures.

Short term (less than one month) movements to pasture areas less than 50 kilometers away occurred generally (and not necessarily every year) towards the end of the dry season. When the rainy season starts early in areas less than 50 km away, livestock can be sent to graze in these areas. 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 (four months) 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.

What we see, therefore, is that the pastoral action space consists of several sub-spatial units defined by the rationale of their use and tenurial status. The spatial sub-units can touch each other, allowing a passage from one to the other, or can be connected by transhumance corridors. What one must note also is that mobility has different justifications, each of which have characteristics that one has to keep in mind when modeling property rights, environmental variability, and livestock development.

In communities where no livestock movement outside of village land was reported, the rationale given was the following: 1) grazing resources on the village land are sufficient for the need of the livestock, and/or 2) the expected cost of movement through livestock losses was too high to justify movement. When considering the dry season, the pastoral action space changes. As the fields are open for residue grazing, this all becomes part of the pastoral action space.

Data Analysis

We now return to the model developed in section 2. Linearizing the model gives the following:

$$\widetilde{SD} = \alpha_0 + \beta_0 Mob + \delta_0^1 \widetilde{CoV} + \delta_0^2 Dummy * \widetilde{CoV} + \gamma_o RQ + \phi_0 \widetilde{Plm}$$
$$\mu_0 \widetilde{Mem} + \varphi_0 \widetilde{Di} + \kappa_0 IC * \widetilde{Mem}$$

$$Mob = \alpha_1 + \lambda_1 SD + \delta_1 CoV + \gamma_1 RQ + \kappa_1 IC * Mem + \xi_1 CostM$$

$$\widetilde{L}_{Crops} = \alpha_2 + \beta_2 Mob + \lambda_2 \widetilde{SD} + \delta_2 CoV + \varpi_2 Ra\tilde{i}n + \phi_2 \widetilde{Plm} + \varphi_2 \widetilde{Di} + \mu_2 \widetilde{Mem} + \kappa_2 IC * Mem$$

where tildes indicate that a variable is in log form.

Stocking rate

The stocking rate is expressed a tropical livestock units (TLU) per hectares available as pasture. Available pasture is equal to rangeland plus ($\frac{7}{12}$ * cropland), to give a seasonally adjusted amount of total grazing land.

Mobility

Livestock mobility is computed as the percent of the village herd absent from the village land during the rainy season.

*Rainfall, Coefficient of Variation of Rainfall, and the Dummy*CoV*

Monthly rainfall data was collected for the period 1988-1996, from 18 rainfall stations. From these records, we calculated annual rainfall and a coefficient of variation of annual rainfall. As noted previously, one of the key hypotheses to be tested is whether areas with relatively higher rainfall variability have different stocking rate response. We have thus created a dummy variable which takes the value of 1 for regions where the coefficient of variation is greater than .22.

Range quality

The range for each of the geographical units identified on the village land will scored from 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.

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

Relative price of livestock to millet (Plm)

The price per kg. liveweight has been estimated using data gathered during the livestock price survey[8], and is divided by the price of millet per kilo.

Distance to Market (Di)

Distance from the community to the major livestock market, as identified by community members.

[8] Results for the price per kg. estimations is given in Appendix 1.

Members (Mem); Members per Hectare (MpH)

This is the total number of households identified in the community-level survey as being members of the community.   We use the total number of households in the mobility equation. However, we use a measure of household density in both the stock density and land allocation equations. If we assumed constant returns to scale in both livestock production and crops, then total members would be the appropriate variable to capture negative externalities arising from imperfect cooperation. However, it is likely that there are also density-dependent intensification effects, on which we have little specific information in the survey, due to the community-level nature of the data collected.   We therefore use the household density measure in the stocking rate and land allocated to crops equations. In these cases, it will not be possible to separate the non-cooperative and density-dependent effects; information on the extent of non-cooperation will only be picked up via the non-cooperation indices, discussed below.

Land allocated to Crops

Land in the community is divided between cropland and rangeland; this variable is the percent allocated to crops.

Cost of Mobility

We have no direct measures on differential costs of mobility across the communities studied. However, we do have information on whether or not the majority ethnic group is traditionally pastoralist, and have created a dummy variable which takes the value of 1 if the ethnic majority is considered traditionally pastoralist (i.e. Peuhl). We also have information on the percent of households considered to be "pastoralist" households. A number of researchers have noted that mobility is likely have high transactions costs associated with knowing where to go, how to acquire information, and who to negotiate with, it is assumed that both communities with a traditionally pastoralist ethnic majority and with a higher percentage of pastoralist households will face lower transactions costs of mobility.

Index of (non-) cooperation

As noted above, in none of the study communities were there explicit rules on maximum stock levels held by households or total stock densities at the community level. 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. We argue here that the extent of "cooperation" reached by a community will be a function of a number of variables that 1) 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) affect the capacity to negotiate and supervise members' actions, and 3) affect the ability of members to reach mutually beneficial agreements amongst themselves. To captures these effects, we derive an index which includes the following variables: 1) stock levels of neighboring villagers using community pastures in the rainy season (RsIN) and in the dry season (DsIN), and dry season stock levels of transhumants (Transh), and 2) the number of community members (TotHH) and the percent of households where the head of household migrated for work in the past year (MigW), and 3) two indices of heterogeneity. The first is a very simple coefficient of variation measure of the cropland holdings (MilHet) (based on information on the smallest, largest and average land size). The second is a measure of the ethnic heterogeneity in the community; there were between one and four ethnic groups in sample villages, and information was also gathered on the proportion of households in each category (EthHet). Ethnic heterogeneity may make informal cooperation based largely on norms more difficult, whereas large differences in wealth reduce the range over which common agreements can be formed (Khwaja, 2000; Alesina and Ferrara, 2000).

Finally, we consider heterogeneity in livestock holdings at the community level, constructed. Unlike the other indicators of heterogeneity, heterogeneity in livestock holdings may have a positive impact on the ability of the community to cooperate by increasing mobility, but should still have negative impact on the ability to cooperate over the management of own pastures, and should thus have a positive impact on stock densities. Because heterogeneity in stock levels may have a different impact on mobility versus stock densities, we will not use this indicator to construct our indices of cooperation, but rather enter this variable directly into the mobility and stock density equations.

Results of a factor analysis – using principal component factors – are presented for the first two factors[9].

	Factor 1	Factor2
Eigenvalue	1.774	1.646
Cumulative	.2534	.488
Scoring Coefficients		
DsIN	-.03545	.43571
RsIN	.37140	.35252
TransH	-.05184	.08495
TotalHH	.23779	.19954
AvgMig	.25295	-.13084
MilHet	.43172	.16073
EthnHet	.23489	-.09125

The first factor has relatively high and positive coefficients on internal variables thought

[9] These two factors had eigenvalues had eigenvalues over 1, the third was just over 1. Because we are attempting to develop indicators of cooperation with the aim of both reducing collinearity as well as having a more parsimonius econometric specification, we chose to keep the first two factors only.

to make informal cooperation more difficult – total households, migration, and cropland and ethnic heterogeneity. Rainy season in-migration also has a relatively large positive coefficient, whereas dry season in-migration and transhumants have negative, though low, coefficients. We interpret this variable as capturing internal factors making cooperation more difficult, and thus refer to it hereafter as NC1. The second factor has high coefficients on both dry and rainy season in-migration, and low but positive coefficient for transhumance. Total households and cropland heterogeneity are also positive, but migration is negative but with relatively low coefficients. This factor is more difficult to interpret, but we consider it to capture the impact of both external and internal effects making cooperation more difficult, and hereafter refer to the variable as NC2. To aid interpretation in the econometric results, we normalize both of these variables to lie in the 0-1 interval.

Regression Results:

Below we present econometric results using three-stage least squares.

	Mobility		**Stock Density**		**%Land Crops**	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Total Households (in natural logs)	.20**	3.71				
Household Density (in natural logs)			1.13**	4.83	-.07**	-2.02
Average Rainfall (in natural logs)	.14	.43	2.63*	2.68	.16	.59
Coef. of Var. of Rainfall (in natural logs)	.07	.56	-.22	-.30	.11	.36
Dummy *Coefficient of Variation of Rainfall (in natural logs)			-.97*	-2.60		
Range Quality Index	1.26**	3.08	.86**	2.04		
Relative Price of Livestock/Grain (in natural logs)			.08	.07	.28*	2.18
Distance to Livestock Market (in natural logs)			-.69**	-.3.61		
Stock of Agricul. Capital	-.005*	-1.69			.002	1.47
NC1*ln(total households)	-.24**	-3.18	.66**	3.26	-.04	-.82
NC2*ln(totalhouseholds)	-.09*	-2.00	.28*	1.80	-.03	-1.20
Heterogeneity in livestock holdings	.003*	1.90	.009*	2.08		
Ethnic Majority Dummy	.14	1.18				
Percent Pastoralist Households	-.12	-.60			.16*	1.65
Stock Densities	.14**	3.20			.006	.21
Mobility			-.13	-.17	.-.07	.-.60
Constant	-.33	-1.11	-2.75**	-3.79	.48**	3.68
	R-squared: .53		**R-squared: .75**		**R-squared: .31**	
	N=36		**N=36**		**N=36**	

Even though the sample size is quite small, the specification does a good job in explaining the variance in stock densities and mobility, though the land allocation equation has fairly low explanatory power. Turning first to the results for mobility, we note the strong negative impact of the two non-cooperation interaction terms, as expected.

Heterogeneity in livestock holdings has a positive and significant impact on mobility, indicating that increased heterogeneity allows community members to induce greater mobility. Total stock density also has a significant positive effect as expected; greater pressure on the home range induces a larger fraction of the total herd to migrate. Interestingly, neither the dummy indicating whether or not the majority ethnic group is traditionally pastoralist nor the percent of households categorized as pastoralist has a significant impact on mobility.

Stock densities are a positive function of household density, as well as the non-cooperation interaction terms. A higher degree of heterogeneity in livestock holdings also leads to higher stock densities. The latter two affects – non-cooperation and heterogeneity – indicate that in some study communities, stock levels are higher than optimal. Higher range quality and mean rainfall, and lower distance to market, all increase stock densities; whereas, estimated livestock prices have no significant effect. Mobility has no significant impact on stock densities, indicating that the decision on mobility is separate from the decision on herd sizes (at least at the community level) and conditioned by total stock levels, but not vice versa.

The coefficient of variation of rainfall has no significant impact, but the dummy interaction term – allowing for a different slope effect in relatively high variability areas – has a significant negative impact. As noted above, this is one of our key hypotheses; our results are consistent with risk-averse producer behaviour models, and do not support "livestock-as-savings" or "herd accumulation in anticipation of drought" hypotheses.

The cropland specification does a relatively poor job in explaining land allocation decisions. Neither mobility nor stock densities have a significant impact on the percent of land allocated to crops, nor do the non-cooperation interaction terms. Peculiarly, household density is negatively related to percent land in crops, which is quite an unexpected result. Given available technology as well as government and NGO technical support, *a priori* it is reasonable to assume that "intensification" of farming operations would more likely lead to a higher proportion of land allocated to crops. As can be seen in Fig. 3 below, however, there is a clear negative relationship between cropland and household density[10]; a relationship that remains strong in the multi-variate analysis. On the other hand, relative livestock prices have a significant positive impact on land allocated to crops, indicating that perhaps despite the emphasis by non-community based organizations on crop technologies, higher population densities are being accomodated by an expansion in livestock activities. It is interesting to note that neither coefficients on the mean nor the variation in rainfall have a signficant impact on land allocated to crops.

Also interesting is the significant and positive impact of the proportion of pastoralist households, depicted in Fig. 3. This may be explained by again appealing to possible impacts of non-cooperation as discussed above – non-pastoralist households may have stronger incentives to privately appropriate land in communities where pastoralist households represent a higher proportion of the community.

Conclusions

There are three main conclusions to be drawn from the above analysis. The first is that even when there are no formal "rules" or regulations regarding stocking rates on common pastures, factors associated with capacity to cooperate at the community level do impact decisions on stocking rates and on mobility. In communities with relatively high scores on our constructed non-cooperation indices, mobility is reduced and overall stock densities are much higher. Though difficult to address directly through policy measures, the results reinforce the notion that devolution of management of resources must consider the capacity of communities to cooperate. Our results do support the notion that measures will have to be developed to offset the negative impacts of heterogeneity-- in terms of wealth and ethnicity—on the ability of the community to cooperate. External pressures on the resource and the number of households, which are more highly correlated with the second index of non-cooperation, also affect mobility and stock

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

density, but the estimated effects are smaller than those associated with the first index.

Second, relative prices favoring livestock actually increase the share of land allocated to crops. This indicates that in these communities, the value of crops (i.e. through use of residues as animal feed) is quite high in livestock activities. Distance to livestock markets identified by community members as being the most important, has a strong negative impact on stock densities. Ideally, we would like to combine this information with studies identifying factors associated with off-take rates; results from this study alone, however, indicate that increasing relative prices for livestock will likely not have a large effect on stock densities per se, but the response is likely to be consistent with increasingly intensified animal production and stronger crop-livestock linkages.

Finally, the impact of rainfall variability is quite pronounced for stock densities, but has no impact either on mobility nor on percent of land allocated to crops. A priori, it would seem reasonable that mobility would be related to rainfall variability. The discrepancy may in part be due to the fact that mobility, by definition, is a flexible response to actual rainfall, whereas stock densities and the percent of land allocated to crops are less flexible and thus depend more on longer-term indicators of variability and mean rainfall realizations. However, consistent with results from Kamara et al. (2001) from the study undertaken in Ethiopia, rainfall variability appears to have no effect on stock densities at relatively low levels; however, there is a strong negative impact on stock densities in communities where rainfall variability is fairly high. This result is important, because many drought mitigation and preparedness measures are predicated on the belief that measures which actually offset the impact of rainfall variability on animal productivity 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 reducing the impact of poor rainfall on animal productivity. Unfortunately, the policy conclusion is thus that measures to mitigate the impacts of drought must simultaneously consider measures to increase off-take, and otherwise reduce stock densities.

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Appendix 1: Descriptive Statistics

We divided the communities into four approximately equal groups by rainfall (above and below 400mm) and coefficient of variation in rainfall (above and below CoV of .25).

	Low Rain, Low CoV		**Low Rain, High CoV**		**High Rain, Low CoV**		**High Rain, High CoV**	
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev
Average Rainfall	451.25	62.21	436.00	39.55	696.67	47.22	711.36	184.18
Coef. of Var. Rainfall	.30	.07	.48	.02	.27	.05	.48	.10
Total Households	38.00	29.93	27.38	16.35	69.58	33.54	157.09	119.20
Total Hectares	1176.94	439.30	1166.91	876.96	1089.23	517.93	1203.64	769.19
Stock Densities	.92	.90	.64	.61	.78	.34	1.78	1.98
% Land in Crops	2.50	4.10	8.75	4.43	19.58	16.29	25.46	15.88
% Land in Pvt. Pasture	14.50	5.98	23.12	6.51	18.83	24.65	15.45	11.50
Rel. Price Livestock	.74	.02	.72	.02	.91	.18	.91	.25
Distance to Market	59.75	36.11	49.38	29.34	28.00	21.92	38.81	24.89
Range Quality	3.38	1.69	3.25	1.67	2.42	1.62	3.00	1.55
Hay	25.20	46.29	12.50	35.35	17.24	39.18	64.32	50.44
Years Cultivating	3.00	4.41	4.50	5.32	18.83	16.21	18.45	10.23

Figure 1: 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.

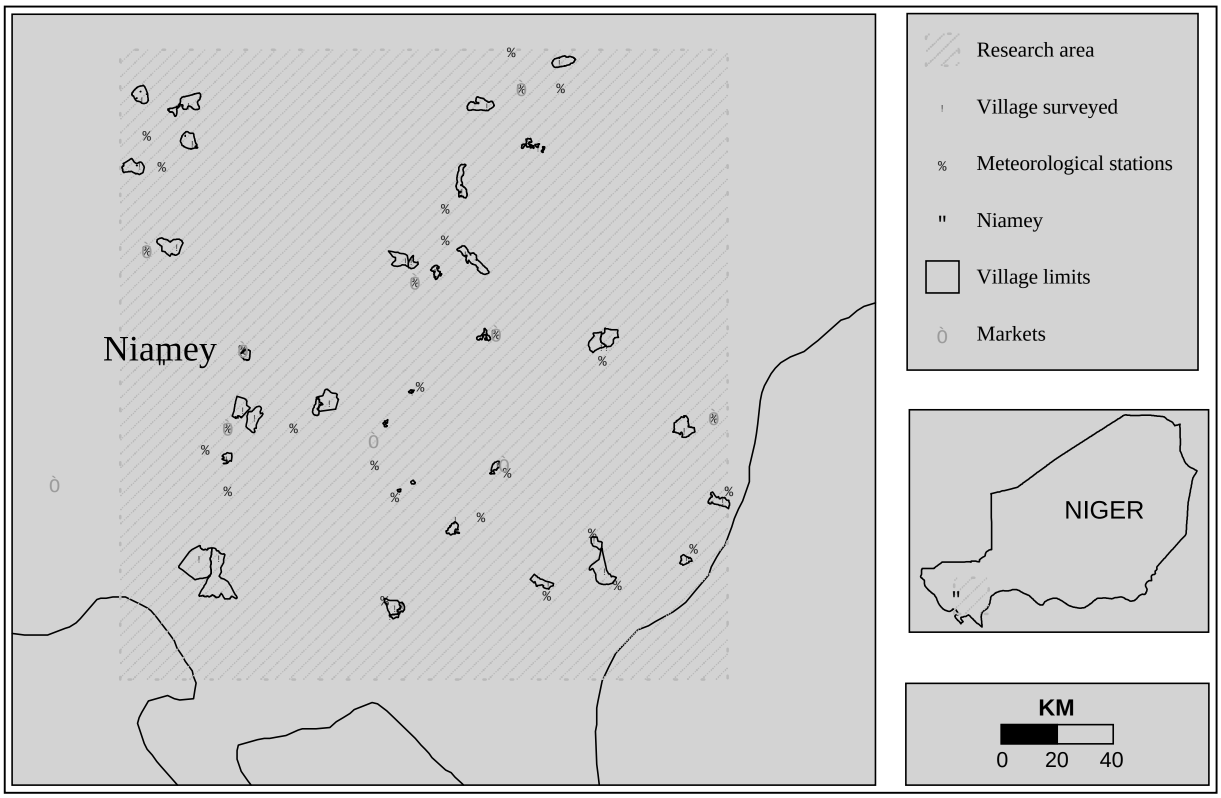

Figure 2: Schematic description of the rainy season pastoral action space. The different spatial sub units are separated by the discontinued line. The first sub unit consists of the village rangeland (A). The second unit consists of rangeland nearby (B) under the jurisdiction of nearby villages or under the jurisdiction of the district chief . Access to this rangeland is never negotiated. A third sub unit consists of rangeland 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).

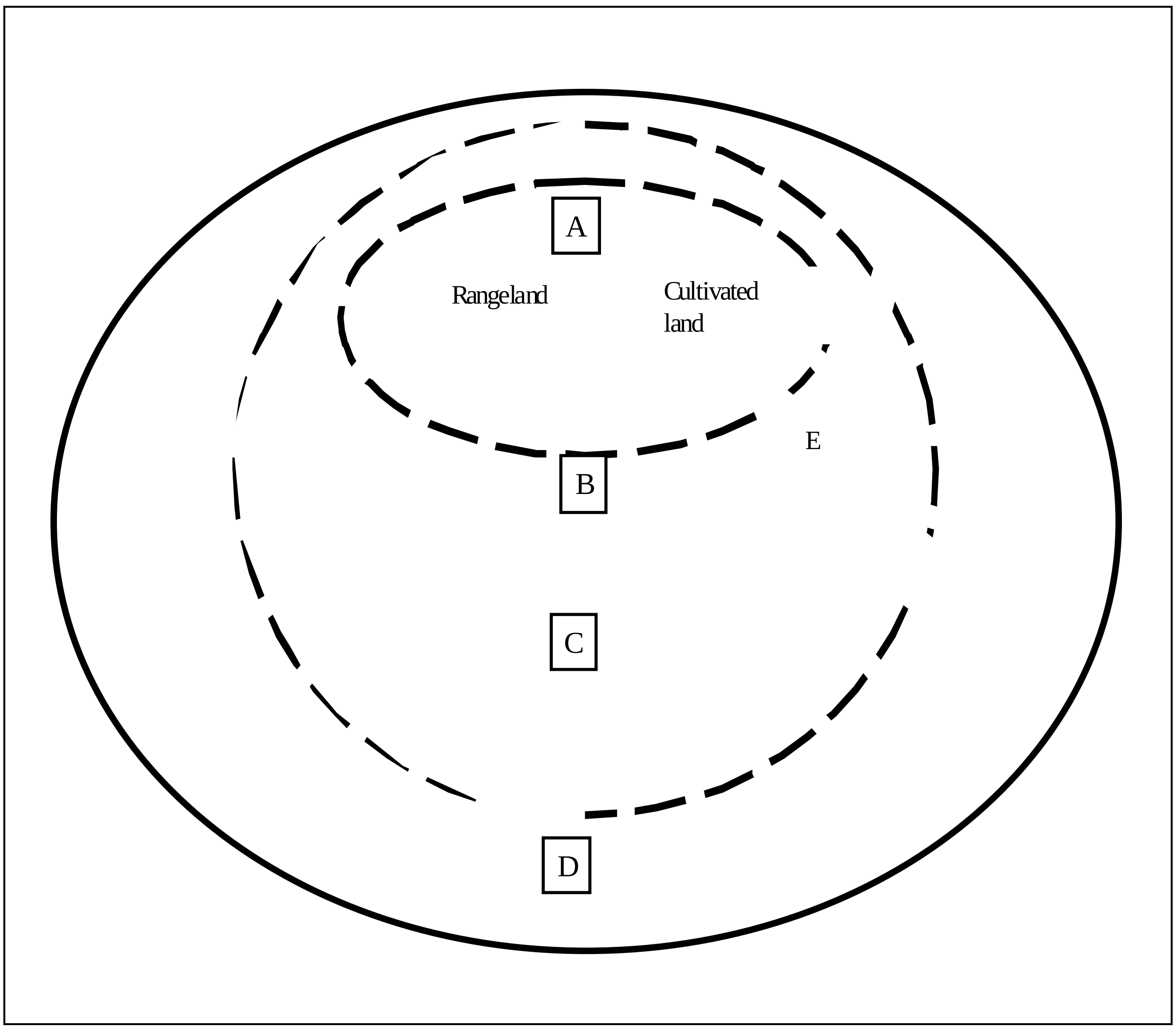

Figure 3: Percent Land Allocated to Crops as a function of Household Densities