Herd Mobility and Waterpoint Use in Northern Kenya

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Abstract
In many regions of the world, property rights to natural resources are held under various forms of communal ownership, which often exhibit flexibility for users to access different resources depending on relative need. Here, we analyze the impact of climatic variability on resource use, and examine the transactions cost of access in these flexible systems.

JEL Classification Codes: O1, Q1

1. Introduction

In the semi-arid regions of north-central Kenya, livestock owners rely on access to multiple pastures and water resources. Land tenure in this region can best be described as ranging from common to open access, though the state is the *de facto* owner of land. It has been argued by a number of authors that mobility and the capacity to access a wide range of resources is required in regions characterized by high spatial and temporal variation in rainfall (Sandford 1983, Coppock 1984, Niamir-Fuller 1999, Behnke & Scoones 1993). Common tenure systems or even open access regimes enable this type of pastoral system to support a large number of people while keeping transactions costs of mobility and flexibility to a minimum. Of course, flexible access for large numbers of users may also lead to over-use of a resource in the absence of well-functioning resource management institutions.

In most studies of mobility, the benefits to mobility are presented in terms of increased average returns to, and decreased variability of, livestock production, and the costs are those associated with transportation of animals. The potential for over-use is largely assumed away (van den Brink et al., 1995). Furthermore, in analytical analyses, access rights are generally considered complete and non-contingent. In the descriptive literature, however, there is a good deal of discussion regarding negotiated access, secondary and tertiary access rights, reciprocal rights of use, and access based on relatively poor rainfall realizations.

In this paper, we develop an empirical model based on a theoretical framework of incomplete and contingent access rights using fuzzy set theory developed in Goodhue and McCarthy (1999). This model enables us to capture the empirical phenomenon of incomplete and contingent access as recorded in the literature cited above, and as a basis for testing whether or not similar patterns of access and use characterize the situation in northern Kenya. In the following section, we review existing empirical literature on herd mobility, present in more detail the conceptual model of fuzzy access rights and herd mobility, and conclude with testable hypotheses regarding the factors affecting household-level decisions on herd mobility. In the third section, we present descriptive statistics of herd mobility and waterpoint use undertaken by households in six communities located in northern Kenya. We compare data on mobility during the drought year of 1991-92 and the 1999-2000 year, which is considered to have been an above-normal rainfall year for the region as a whole. In the fourth section, we present results of an ordered logit model, where the number of waterpoints used is estimated as a function of household-level variables and community-level waterpoint characteristics. In the fifth section, we conclude by considering extensions to the empirical work.

2. Literature Review and Conceptual Framework: Herd Mobility

It is widely accepted that traditional rangeland management systems based on mobility enabled herders to engage in opportunistic grazing strategies that both increased average herd productivity and reduced riskiness of production resulting from climatic variability (Niamir-Fuller 1999, Bovin and Manger 1990, Scoones 1995, Freudenberger & Freudenberger 1993). It is also posited that traditional systems reduce transactions costs associated with accessing range resources, thus enabling resource users to fully benefit from flexibility in responding to climatic variability. In order to cope with climatic variability, pastoral systems are not only flexible in the number of options open for mobility, but also with respect to other inputs such as feed substitutes, labor allocation, etc. (Ngaido, 1999). Except in a very few instances, pastoral families are likely to be engaged in a wide-range of activities, and these opportunities may also influence benefits and costs of livestock production as well as incentives for mobility (Toulmin 1983, Bonfiglioli, 1990).

In the early 1990's, the "New Rangeland Ecology" (NRE) school of thought developed, which focused on flexibility and mobility -- a departure from the classical paradigm of rangeland management, which is thought to have underestimated the importance of mobility (O'Connor & Roux, 1995 Hiernaux, 1996, Behnke Scoones and Kerven 1993). Proponents of NRE maintain that climate variability is the major factor determining vegetation availability and structure; grazing pressure is held to have very little effect on forage characteristics except in extremely densely populated settlement areas (i.e. around boreholes). Though generally ignoring the impact of grazing pressure on animal productivity and severity of drought in terms of animal production, proponents have still argued cogently about benefits of mobility in terms of using range resources more efficiently via "opportunistic" grazing strategies (Sandford, 1983) and in terms of reducing variance in animal production due to spatial variability in climatic conditions.

Niamir-Fuller (1999) considers factors affecting spatial and temporal components of mobility -- such as distance and timing of mobility – which include water and forage availability, localized climatic conditions, potential economies of scale in communal herding and drawing water at wells, and political factors such as relations between pastoral communities, and between pastoralists and non-pastoral communities (Niamir-Fuller, 1999). Kerven and Cox's study (1996), based on interviews of pastoralists in southern Ethiopia, identifies water during the dry season – not forage – as the major constraint to mobility (see also Coppock, 1994). Still, forage is often an important constraint; Smith et al. (2001) reports that pastoralists in northern Kenya ranked water and forage as the most important constraints.

The historical reduction in mobility in pastoral areas has been ascribed to various factors, including major droughts with devastating livestock losses, government policies promoting sedenterization, public investments in fixed-location rural services (health clinics, school buildings), population growth and expansion of agriculture, rural violence, and growing economic vulnerability of pastoral groups due to policies favoring agriculture (Niamir Fuller, 1999). Some researchers also believe that land use changes precipitated by borehole development in the 1960's and 1970's changed land values and triggered "enclosure" movements which further constrained mobility of herds (Behnke, R. 1988).

Considering the drought cycle specifically, Toulmin (1988) describes traditional pastoral strategies during the cycle as occurring in four stages – 1) dry year, leading to 2) drought year, 3) recovery stage, and 4) "normal" conditions stage. Toulmin maintains that herders first attempt to increase their mobility in response to low rainfall realizations, and perhaps to further diversify species held; they may also rely on reciprocal claims to resources (financial, labor, pasture, other natural resources, etc.) with wealthier kin or clan members. As conditions worsen, some herders attempt to sell certain animals, but by this time, it is hypothesized, prices have generally dropped and animals are generally in poor condition. Some families may try and send members in search of wage work, or famine relief camps if these exist. As the drought ends, those with stock remaining attempt to recover as quickly as possible, meaning that offtake is likely to be at its lowest. Also, prices may rise during this period[1]. This is followed by the "normal" period, where both herd sizes and offtake increase. Unfortunately very little empirical data on mobility in different rainfall years exist.

To summarize, mobility is believed to be one of the most components of pastoralist strategies, though issues surrounding access to, and management of, natural resources have generally been down-played or simply ignored, even in areas facing major violent conflicts over access to resources. In this section, we will present a conceptual framework for analyzing access rights to resources that focuses quite specifically on the nature of access rights and how these operate in pastoral areas.

First, we consider that herders choose whether or not to move to a new pasture area depending not only on their own access rights to that new area, but on the access rights of other herders as well. Thus, the decision to move to new areas will depend on your absolute access rights and also on your rights relative to all others with some rights to various resources; the greater your absolute and relative rights, the more mobile you will be. Also, we expect that the number of points accessed will increase when "transit" costs decline; that is to say, in years with average or above-average rainfall, we would expect more points to be accessed because water and forage resources are likely to be more readily available both at the water point and while in transit. Furthermore, if access rights are contingent on relative rainfall realizations (i.e. if my access rights are "greater" when my area receives a relatively bad rainfall realization), then we would expect more points to be accessed by households living in areas with relatively poor realizations. Note the direct and indirect effects of rainfall; higher rainfall in a region directly reduces transit costs for all pastoralists, but relative access rights will be equalized, which may lead to less mobility. To summarize, we expect mobility to be highest for those households in areas with relatively poor rainfall realizations but that are also located in regions that received relatively good rainfall. Alternatively, we expect mobility to be lowest when rainfall is generally poor, but one's particular area received relatively favorable rainfall. In between are the cases where rainfall is generally poor and is bad in your core grazing area, and where rainfall is generally good and good in your core grazing area. In terms of drought vs. non-drought years, we hypothesize that mobility will be lower in drought years, since many observers hypothesize that drought years are characterized by uniformly poor rainfall realizations. Instead, mobility will be greater during years of average or above-average rainfall, to the extent that idiosyncratic differences in rainfall realizations are more prominent during these years.

Note that the benefits of flexible access rights in terms of both improved mean incomes and reduced variability of incomes comes from increased and less costly mobility during years characterized by idiosyncratic rainfall realizations. Because many authors believe that the benefits to mobility are most important for mitigating the impact of drought, it is important to try and characterize whether factors influencing the mobility decision differ depending on whether it is a drought or "normal" year[2].

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[1] Data on livestock "prices" are nearly always revenue per head. And, it is not at all clear whether lower revenues per head are due to some exogenous drop in demand, or rather, if the quality and size of animals sold declines. In fact, its like saying the price of maize dropped by 50%, when you first sold a 100 kg. bag, but next sold a 50 kg. bag. Though most people would find this outrageous when discussing crops, the literature referring to livestock prices almost uniformly ignores this.

[2] Technically (and by simply looking at the descriptive statistics), it seems that we will certainly have "identification" problems in terms of separating out factors affecting the "demand" versus the "supply" of access to waterpoints.

To test hypotheses regarding mobility, rainfall received and variation in rainfall, in section 3, we first present statistics on rainfall and normalized difference vegetation indices (NDVI) statistics in six different areas of northern Kenya: North Horr (NH), Kargi (KA), Loglogo (LL), Dirib Gombo (DG), Suguta Marmar (SM) and N'Gudas (NG). We present information on long-term averages, coefficients of variation, and NDVI information for 1992 and 1999. In section 4, we consider actual patterns of mobility undertaken by households in 1992 vs. 1999; extensive data was collected by project members of the Global-Livestock Collaborative Research Support Program: (what is their actual title?). In this section, we also consider indicators of how costly it is to move (in terms of negotiating access, making exchanges, or abiding by limits), and relate these indicators to NDVI and spatial variability indicators from section 3. We can thus examine whether or not mobility is "less" costly in areas with relatively high but spatially variable rainfall. In section 5, we can present results of a statistical analysis of factors affecting mobility in 1999.

3. Descriptive Statistics of Spatial and Temporal Mobility

In this section, we present some basic descriptive rainfall and normalized difference vegetation index (NDVI) statistics. NDVI is a measure of photosynthesis activity of vegetation obtained from satellite images and is calculated from the near infrared and red bands: NDVI = (Near Infrared - Red)/(Near Infrared Red). The available time series data on rainfall can be quite poor for much of Africa because weather stations are sparse, particularly in the semi-arid and arid regions. Additionally, standard techniques for estimating rainfall surface data rely on interpolation measures that calculate estimated rainfall between two stations by various "smoothing" techniques, meaning that spatial variability is likely well under-estimated in these series. On the other hand, long time-series data of NDVIs are also available. While there is a positive correlation between rainfall and NDVI, NDVI may itself be a function of human behavior as well as rainfall. For instance, increased cropping or bush encroachment due to improper grazing pressure may increase NDVI, but it would decrease available forage, and may also increase variability in available forage. Despite problems of comparing NDVI and rainfall in terms of levels, we nonetheless posit that measures of spatial variation constructed using NDVI data suffer fewer potential problems of endogeneity, and use these data in the analyses that follow. Table 1 gives long-term average mean rainfall (Hutchinson 2001), the average and coefficient of variation of NDVI over the past 18 years, and average NDVI for the months of May and August (Clark Labs, 2000). In general, May is the wettest month of the year, whereas August is generally the driest month.

Table 1: LONG TERM RAINFALL AND NDVI VALUES

+: data source: Hutchinson.

CV = coefficient of variation

Community	Rainfall Mean +	Longitude	Latitude	NDVI Mean	NDVI CV	NDVI MayMean	NDVI AugMean
NH	230	37.0700	3.3240	92	0.0712	103	88
KA	319	37.5739	2.4991	105	0.0715	117	97
LL	422	37.9055	2.0131	133	0.1170	156	114
DG	625	38.0591	2.2972	135	0.1132	167	113
SM	542	36.6830	0.8360	162	0.0671	177	166
NG	609	36.0667	0.5000	166	0.0611	183	181

North Horr (NH) and Dirib Gombo (DG) receive the lowest and highest average rainfall, respectively; and, average NDVI correlates strongly with the rainfall data, with the exception of Dirib Gombo, which has only the third highest average NDVI. In fact, Dirib Gombo is located close to Mt. Marsabit, which receives the highest rainfall in the area; the high rainfall figure, obtained by interpolating rainfall data, may overestimate rainfall in the nearby, but lower-lying surrounding areas such as Dirib Gombo. The coefficient of variation of average annual NDVI (NDVI CV), yields the observation that NH, which is the driest region in the study area, also exhibits very low NDVI CV. The coefficient of variation is quite high in the "medium" rainfall region of LL, and also high in the highest rainfall region, DG. A quick look at average NDVIs in the wettest (May) and driest (August) months of the year, found in the last two columns of the table, highlights the fact that monthly NDVIs are indeed higher during wet (May) months and lower during dry (August) months, and that the rank of communities remains overall unchanged for both months compared with the annual average.

Spatial variation and 'patchiness'

In order to account for spatial variation in landscapes between communities we used NDVI data obtained from Clark Labs to generate fragmentation statistics. We analyzed an area of 40 km radius around each of the 6 communities, since the majority of herd movements fell within this area. We define spatial variation in two ways: first using 36 absolute categories of NDVI values (36 fixed equal range categories[4]) and a second using relative categories (9 categories of variable range[5]). We consider that each category corresponds to a different 'patch type'. The first approach allows us the compare overall patchiness across communities, while the second approach looks at the relative patchiness of a particular area, which may be a better measure on which to compare movements of herds within a given area between drought vs. non-drought years. We also constructed two sets of maps of NDVI values for the 40 km radius area, one for the 36 absolute categories (each color corresponds to the same NDVI range for all six regions), and another set for the 9 relative categories (colors are map specific).

We next constructed 2 different landscape level fragmentation indices: the aggregation index (AI), which measures the mean value of degree of disaggregation of different patch types in the landscape, and the contagion (CONT) index, which measures both dispersion and interspersion; both defined more fully below. The indices were constructed for both landscape characterizations based on absolute (36) and relative categories (9). We calculated the indices for 4 months (March, March, August, December), which are on average the driest and wettest months of the seasons (long and short, rainy and dry seasons).

[3] The correlation coefficient for NDVI of the community center coordinate and Hutchinson rain data is 0.9950, while the correlation coefficient for NDVI average over 40km radius around the community and the Hutchinson rain data is 0.8815.

[4] We use 36 categories, so that the more uniform areas still include at least three different categories

[5] 9 equally spaced categories within the NDVI range of the specific area (maxNDVI-minNDVI). Assignment of category follows the Jenks optimisation method (Jenks, 1967). Thus each map has 9 categories but ranges differ.

Aggregation index:

$$AI = \left[\sum_{i=1}^{m} \left(\frac{g_{ii}}{\max \to g_{ii}} \right) P_i \right] (100)$$

where:

g_{ii}	=	number of like adjacencies (joins) between pixels of patch type (class) i based on the single-count method.
max-g_{ii}	=	maximum number of like adjacencies (joins) between pixels of patch type (class) i (see below) based on the single-count method.
P_i	=	proportion of landscape comprised of patch type (class) i.

range: $0 \leq AI \leq 100$

Given any Pi, AI equals 0 when the patch types are completely disaggregated (i.e., no like adjacencies), while AI increases as the landscape is increasingly aggregated. When the landscape is completely uniform it equals 100.
The AI index at the landscape level is computed as an area-weighted mean class aggregation index, and each class is weighted by the proportion of area covered in the landscape. (McGarigal et al. 2002)

Contagion index:

$$CONT = \left[1 + \frac{\sum_{i=1}^{m} \sum_{k=1}^{m} \left[(P_i) \frac{g_{ik}}{\sum_{k=1}^{m} g_{ik}} \right] \otimes \left[\ln (P_i) \frac{g_{ik}}{\sum_{k=1}^{m} g_{ik}} \right]}{2 \ln (m)} \right] \oplus 100$$

P_i =proportion of the landscape occupied by patch type (class) i.

g_{ik} =number of adjacencies (joins) between pixels of patch types (classes) i and k based on the double-count method.

m =number of patch types (classes) present in the landscape, including the landscape border if present.

range: $0 < CONT \leq 100$

CONT is close to 0 when the patch types are very disaggregated (i.e., every cell is different patch type) and interspersed (equal proportions of all pairwise adjacencies). When all patch types are maximally aggregated the index is equal to 100 (e.g. only one patch). If a single class occupies much of the landscape, the index is high, and low otherwise. This index is affected by both the dispersion and interspersion of patch types. Low levels of dispersion (i.e., high proportion of like adjacencies) and low levels interspersion (i.e., inequitable distribution of pairwise adjacencies) results in high contagion. (McGarigal et al. 2002)

Table 2: SPATIAL VARIABILITY

1992

	AI 36	CONT 36	AI 9	CONT 9	Ndvi 40km Mean
NH	63.3	30.2	42.1	22.8	89.3
KA	52.3	33.2	55.6	34.3	98.4
LL	41.8	37.5	63.5	43.9	114.5
DG	39.4	30.4	58.0	34.4	115.2
SM	34.5	24.0	43.9	24.5	143.1
NG	28.5	18.1	**38.9**	16.7	151.7

1999

	AI 36	CONT36	AI 9	CONT9	Ndvi 40km Mean
NH	53.0	31.0	45.6	27.9	91.3
KA	44.9	34.5	66.6	42.0	105.3
LL	26.8	26.9	49.9	30.2	134.2
DG	33.0	28.9	51.3	30.0	132.0
SM	39.1	22.8	43.3	22.1	159.5
NG	31.8	20.6	**38.9**	18.7	163.8

Figures for AI and CONT presented in Table 2 above are the average of the four monthly values; monthly data were highly correlated, with exception of a few pairs for the optimized category case in 1992. We first note that whereas the contagion indices and the aggregation index using the 9 optimised categories perform similarly, the aggregation index using the 36 standard categories performs quite differently. We have highlighted the boxes where spatial variation is higher when comparing the two years; for instance, all AI and CONT indices for LL and DG are lower in 1999 vs. 1992, so these are shaded. It is striking that, while mean NDVI is uniformly higher in 1999 as expected, measures of spatial variation do not correlate with drought vs. non-drought conditions. According to the contagion and 9 category aggregation indices, spatial variability is higher in 1999 in the three mid-level average ndvi areas, which means that spatial variability is lower in the non-drought year in the highest ndvi and two lowest ndvi areas. Also interesting to note is the fact that spatial variation is generally lower in the drier areas in any year, except for the driest area, NH.

Yet another aspect to consider is seasonal variation. Though the spatial variation measures were correlated across months, such information does not sufficiently capture differences in seasonal variability through the year. As an indicator of seasonal variability, we calculate the coefficient of variation of average monthly NDVI throughout the year. Table 3 below presents a summary of the intra-annual NDVI CV information for 1992 and 1999.

Table3: NDVI and TEMPORAL DIFFERENCES

Community	NDVI CV 1992	NDVI CV 1999
NH	0.0638	0.0590
KA	0.0586	0.0580
LL	0.1237	0.1303
DG	0.1438	0.1755
SM	0.0925	0.0802
NG	0.1098	0.0797

NH and KA exhibit very low NDVI CV in both time periods, but whereas KA exhibits moderately low spatial variation, NH exhibits fairly high spatial variation, particularly in the drought year. DG has the highest seasonal variability, but exhibits consistently low spatial variability. LL and NG both exhibit high seasonal variation, but LL is relatively spatially homogeneous, whereas NG is generally the most spatially variable. Comparing 1992 and 1999, while the NDVI average is uniformly higher in 1999, the CV is higher only for LL and DG. Thus, there is little correlation between drought and non-drought years and patterns of seasonal variability.

To summarize, NDVI indices are uniformly higher in 1999 vs. 1992, as we expect. However, differences in variability, both seasonal and spatial, do not correlate as well with drought vs. non-drought conditions, but do correlate well with each other. Given the observed pattern of spatial and seasonal variability, we expect that mobility will be less costly in 1999 versus 1992 in DG and LL, and, to a lesser extent, in SM; and is likely to be more costly in NH , KA, and NG.

4. Descriptive Statistics of Permission, Exchanges, and Limits, by Area

In this section, we present descriptive statistics on the different waterpoints accessed by households, as well as data on the number of total waterpoints visited by households. The number of different waterpoints accessed by households is not necessarily the same as the number of visits by households to waterpoints, since in many cases, households visited the same waterpoint more than once during the year. We also distinguish between mobility of the base camp herd (near the village) versus the satellite herd (more remote pastures) (c.f. McPeak 2000). We make the distinction since factors driving mobility may differ between base and satellite camps, primarily because base camp movements may be affected by the crop cycle, whereas satellite camp movements take place largely outside the cropped areas.

In section 2, we hypothesized that access rights may either be incomplete and/or state contingent. We do not directly observe whether access and use rights are incomplete, but observe whether or not permission was required to access a waterpoint, whether limits were imposed on households using certain waterpoints, and whether exchanges (in terms of money or animals transfers) were required to access the resource. We hypothesize that requesting permission, making exchanges, and facing restrictions/limits on use all constitute transactions costs of accessing and using waterpoint resources and surrounding pastures. Alternatively, where these transactions costs are zero, we consider rights to be complete.

In order to check for state contingent rights, we consider the difference in these transactions costs between 1992 and 1999. Given the NDVI and rainfall data presented above, we expect that, if rights are state contingent, transactions costs should be somewhat lower in 1999 in NH, KA, and LL because of generally higher spatial variability and higher average rainfall. Transactions cost may be higher or lower in DG, SM, and NG; these areas also received higher average rainfall, but spatial and seasonal variability was lower in 1999 vs. 1992.

Before proceeding to the transactions costs statistics, we present basic statistics on the number and types of waterpoints used in each of the six communities, differentiating between base and satellite camp.

Waterpoints

Tables 4 and 5 give data on waterpoints used for base camp in 1992 and 1999. The first five columns give data on the number of waterpoints used by type of waterpoint – surface, hand-dug well, and bore-hole. The last column gives the number of different waterpoints accessed.

Table 4: Number of Base Camp Waterpoints, 1992 (B92):

	#WP Total	#WP Hand-dug	#WP Surface	#WP Borehole	Total Points Visited
NH	31	24	7	0	90
KA	9	8	1	0	28
LL	13	5	1	5	21
DG	10	5	0	5	46
SM	33	18	10	4	51
NG	11	1	9	1	43

Table 5: Number of Base Camp Waterpoints, 1999 (B99):

	#WP Total	#WP Hand Dug	#WP Surface	#WP Borehole	Total Points Visited
NH	27	18	7	0	104
KA	8	5	1	2	88
LL	21	2	9	10	67
DG	9	6	1	2	41
SM	36	11	15	10	60
NG	15	2	11	2	58

[6] Here, we should say something about number of points visited in 2000, noting that we just don't have the corresponding NDVI or rainfall data for 2000, but with the exception of Kargi, the number of points visited within a region and the number of visits to different waterpoints is indeed higher in 1999
than 2000, with the exception of Kargi; statistics presented in an Appendix ??.

Starting with Base Camp 1992, we see that SM has the greatest total number of points used. This is followed by NH and LL, and in turn by DG and KA. Herders in NG rely heavily on surface waterpoints; even in the drought year of 1992, people of NG relied upon only two non-surface points. In 1999 (B99), the ranking of communities by total number of waterpoints used remains the same as in 1992 (B92). However, in three of the communities, slightly fewer waterpoints were accessed in B99 (DG, KA, and NH), whereas total number of waterpoints accessed increases slightly for NG and SM, and rather substantially for LL. In particular in LL, the number of boreholes accessed by households increases substantially from B92 to B99. Also whereas only one surface waterpoint was mentioned in LL in B92, 10 different surface waterpoints were mentioned in 1999. In fact, one would have expected that surface water point use would have increased substantially in 1999 vis-à-vis 1992; however, while this is generally true, the increase is only dramatic in the case of LL.

Whereas the total number of waterpoints accessed exhibits no general trend, the total number of visits by households does show a general increase. In fact, number of visits increases in five of the six communities, and does so dramatically in KA and LL. Number of visits actually decreases slightly in 1999 in DG. Thus, total base camp visits only roughly follow our predictions.

Transaction Costs of Mobility

Transaction costs are proxied here by the need to ask permission to access a waterpoint, by the presence of limits to the use of the waterpoint and the need to pay (cash or livestock) for access. Here we present in turn the descriptive statistics of permission, limits and exchanges for 1992 and 1999. First we present statistics on the number of waterpoints at which at least one household asked permission, and the number of household visits to waterpoints where the household had to ask permission. This is followed by information on the number of points and the number of household visits where households faced limits or restrictions on accessing various resources and information on whether exchanges occurred so that a household could gain access a waterpoint. We note that, for both limits and exchanges, information is presented on the subset of waterpoints where permission was required.

Table 6a: Permission by Water Point and by Household, Base Camp 1992 (B92)

	Waterpoints				Households			
	Total Points	Perm Yes	Perm Mixed	Perm No	Total Visits	Perm-No	Perm-Yes	% Yes
DG	10	8	2	0	46	6	40	87
KA	9	2	3	3	28	14	8	29
LL	13	0	0	13	21	20	0	0
NG	11	0	2	9	43	39	2	5
NH	31	20	2	9	90	23	60	67
SM	30	1	0	33	51	39	1	2

Table 6b: Permission by Water Point and by Household, Base Camp 1999 (B99)

	Waterpoints				Households			
	Total Points	Perm Yes	Perm Mixed	Perm No	Total Visits	Perm- No	Perm- Yes	% Yes
DG	9	8	1	0	41	4	35	85
KA	8	2	3	3	88	44	39	44
LL	21	0	0	21	67	64	0	0
NG	15	2	1	12	58	54	3	5
NH	27	18	5	4	104	26	67	64
SM	36	0	0	34	60	58	0	0

In 1992, permission was required by all water users at 8 out of 10 points in DG, 20 of 31 in NH, and 2 out of 9 water points in KA. Furthermore, in DG, KA, NG and NH, there was at least one point where some households requested permission and some did not (the "Perm Mixed" column). No permission was requested by any household in LL; and was required at only one point in SM. This coincides fairly well with data on the number of times households asked permission to access a waterpoint. In KA, however, though 56% of the water points mentioned by survey respondents required permission (if we consider the "mixed" points), only 29% of respondents asked permission at any watering point, indicating that the non-permission points were used slightly more frequently.

Data on permission to access base camp waterpoints in 1999 is very similar to that for 1992. Number of points where permission was required by all users declined in NH, but the number of "mixed yes/no" waterpoints increased by three, and the number of waterpoints where permission was not required declined by four. As noted above, the number of visits by households increases substantially in 1999 vs. 1992, except for DG, but the percent of households requesting permission remains very similar, except in the case of KA, where requesting permission actually increases. We note that we expect transactions costs to be higher in KA in 1999, since both spatial and seasonal variation are lower in that year.

In Tables 7a,b and 8a,b, data is presented on limits and exchanges, for the subset of waterpoints where permission was required. Tables 7a,b give data for limits, and 8a,b for exchanges.

Table 7a: Limits where Permission is Required, B92

	Waterpoints			Households		
	Yes, all hh's	Mixed Yes/No	No, all hh's	Number hh Visits	Number of hh: Limits	% of hh's facing Limits
DG	3	3	4	40	11	28
KA	2	2	1	8	5	62
LL	n/a	n/a	n/a	n/a	n/a	n/a
NG	1	0	1	2	1	50
NH	3	2	17	60	5	8
SM	1	0	0	1	1	100

Table 7b: Limits where Permission is Required, B99

	Waterpoints			Households		
	Yes, all hh's	Mixed Yes/No	No, all hh's	Number hh Visits	Number of hh: Limits	% of hh's facing Limits
DG	1	3	1	35	11	31
KA	3	1	1	39	28	72
LL	n/a	n/a	n/a	0	n/a	n/a
NG	1	0	2	3	1	33
NH	3	2	18	67	6	9
SM	n/a	n/a	n/a	0	n/a	n/a

At nearly half the waterpoints in DG and KA, some limits were imposed on at least some users; it is interesting to note that these are precisely those communities with the least total number of waterpoints accessed. Limits were also imposed at five points in NH in both 1992 and 1999. In fact, in terms of waterpoints, there is a very slight decrease in the total number of waterpoints where at least one household faced limits. The number of households facing limits actually increases, but this is mainly due to a dramatic increase in limits in KA.

Table 8a: Exchanges where Permission is Required, B92

	Waterpoints			Households		
	Yes, all hh's	Mixed Yes/No	No, all hh's	Number hh Visits	Number of hh: Gave Something	% of hh's that Gave
DG	10	0	0	40	40	100
KA	0	0	5	8	0	0
LL	n/a	n/a	n/a	0	n/a	n/a
NG	1	0	1	2	1	50
NH	0	1	21	60	1	2
SM	1	0	0	1	1	100

Table 8b: Exchanges where Permission is Required, B99

	Waterpoints			Households		
	Yes, all hh's	Mixed Yes/No	No, all hh's	Number hh Visits	Number of hh: Gave Something	% of hh's that Gave
DG	4	1	0	35	34	97
KA	1	1	3	39	8	21
LL	n/a	n/a	n/a	0	n/a	n/a
NG	1	0	2	3	1	33
NH	0	1	22	67	1	1
SM	n/a	n/a	n/a	0	n/a	n/a

Regarding whether households had to give something in order to access the water point (cash, animals, both), we see that this is quite limited, mainly to DG, where a transaction occurred at every waterpoint where permission was required. However, there was but one household in NG and another in SM required to pay in order to access a water point in 1992. In both of these cases, oddly enough, the head of household was female. The number of households required to give something fell in 1999 in DG, but actually increased in KA. This too roughly corresponds with predictions; again, conditions were much less variable in time and space in KA in 1999, but were relatively more variable in DG in 1999.

Also interesting to note is that in DG in 1992, of the 40 times households were required to give something, 11 times they also faced limits (about 28%); in 1999, of the 34 times households gave something, 7 times they faced limits (about 21% of the time).

A few interesting points arise from the above descriptive statistics. First, permission, payment for access, and limits were all higher in DG and KA, where the total number of points used was the lowest. Secondly, whereas permission is required of almost all households in NH – where there were many water points mentioned -- exchanges and limits applied at far fewer of the waterpoints. This contrasts with SM, which is also characterized by many water points. In SM, neither permission, nor payments nor limits were important. Unlike households in NH, households in SM have access to many surface water points – though they still appear to rely on wells too. Households in NG relied almost exclusively on surface water during 1992 for base camp animals; permission was required at only two points. In LL, no permission was required at any waterpoint; though, evidence suggests that households do pay for petrol to operate the equipment at the boreholes there. It may also be the case that households have to "pay" to use the machine dug and operated boreholes in terms of maintenance or other fees; unfortunately, we have no further information on this.

At this point, we might step back and consider some of the hypotheses regarding mobility stemming from the flexible access rights model. Recall that we hypothesize that, for any household, the number of waterpoints accessed will increase when transit costs of mobility decline and when access costs decrease. One would expect that in 1999, more resources would be more readily available "along the way", so that more points should have been accessed. Access rights at the household level should be relatively stronger in DG, LL and SM, so that this should also reinforce the increase in number of points used due to lower transit costs. While the data generally supports these hypotheses, differences between base camp movements in 92 vs. 99 are quite limited in terms of percentage of points requiring permission, exchanges or limits, or in percentage of households facing permission, exchanges or limits. The biggest difference is in the total number of visits by households, which is much greater in 1999 – even for non-surface waterpoints.

In the next section, we present statistics on waterpoints accessed and the number of visits by households to different waterpoints by satellite camp herds, as opposed to base camp movements that we just examined. Tables 9 & 10 present data on number and types of waterpoints used by satellite camp herds, and the total number of visits broken down by visits to surface and non-surface waterpoints. Figure 2 in the appendix presents a graphic representation of the number and types of points used in 1992 and 1999.

Table 9: Number of Satellite Camp Waterpoints, 1992 (S92):

	#WP Total	#WP Hand-dug	#WP Surface	#WP Borehole	Total Points Visited
NH	50	31	19	0	102
KA	26	19	2	3	97
LL	60	29	15	15	115
DG	15	4	3	8	34
SM	39	10	21	6	60
NG	14	2	12	0	53

Table 10: Number of SatelliteCamp Waterpoints, 1999 (S99):

	#WP Total*	#WP Hand Dug	#WP Surface	#WP Borehole	Total Points Visited
NH	49	33	12	0	85
KA	20	12	4	3	96
LL	68	12	38	14	146
DG	17	6	2	7	38
SM	34	12	13	5	58
NG	14	1	12	1	47

*#WP Total does not equal the sum of hand-dug, surface, and borehole points in 1999; in DG this is due to households accessing machine-dug wells, and in LL, private wells (2) and private taps (1).

Compared with base camp, in general more waterpoints were used by satellite camp herds, roughly following the same rank of total water points used with the exception of LL, which jumps from third place to first. The number of waterpoints used in DG, KA, LL, and NH are at least 30% greater for satellite vs. base camp herds, whereas the number of points is roughly similar for base and satellite herds in NG and SM. Households in LL relied on a relatively large number of hand-dug wells, followed by surface water and boreholes. Households in DG and KA used a relatively small number of surface water points, and relied more heavily on hand dug wells, and relatively more boreholes in DG. As with base camp waterpoint use, there were a large number of surface waterpoints used by households in SM and NG. Households in NH also named a fair number of surface waterpoints, but almost twice as many hand-dug well waterpoints. The total number of visits in 1999 to different waterpoints is greater in DG and LL, as expected, and lower in NG, NH, also as expected, and roughly unchanged in KA and SM.

Data on permission, limits and exchanges for S92 and S99 are given below in Tables 11a,b, 12a,b and 13a,b.

Table 11a: Permission, By Water Point, Satellite S92

	Waterpoints				Households			
	Total Points	Perm Yes	Perm Mixed	Perm No	Total Visits	Perm-No	Perm-Yes	%Perm Yes
DG	15	10	1	4	34	9	25	74
KA	26	15	6	4	100	43	52	52
LL	60	0	0	60	115	110	0	0
NG	14	1	0	13	53	50	1	2
NH	50	33	2	15	102	23	75	74
SM	39	1	0	38	61	59	1	2

Table 11b: Permission, By Water Point, S99

	Waterpoints				Households			
	Total Points	Perm Yes	Perm Mixed	Perm No	Total Visits	Perm-No	Perm-Yes	%Yes
DG	17	12	1	4	38	6	32	84
KA	20	7	6	7	96	61	35	36
LL	68	0	0	68	146	146	0	0
NG	14	2	0	12	47	45	2	4
NH	49	39	4	6	85	17	68	80
SM	34	3	0	31	58	55	3	5

As with base camp points, permission was required at majority of points in DG, KA and NH. The percentage of points where permission was required for at least some herders in DG is slightly lower vis-à-vis the case for base camp across both years, slightly higher for NH, and higher in KA. As with base camp herds, no permission was required at points in LL in either year. Permission was required at one point each in SM and NG – the same points named by the same households as those for B92 – and by two and three points respectively in 1999.

Permission was required at roughly the same number of waterpoints in S99 and S92 in DG and SM. The number of waterpoints where all were permission was required either by all or some users was slightly greater in NH as expected, but lower in KA; we expected permission to actually be greater in KA in 1999. On the other hand, the proportion of households in KA actually requesting permission decreased, which may be partially explained by the fact that a larger percentage of waterpoints were "mixed" and lower percentage of "all yes" than in S92.

Table 12a: Limits where Permission Required, S92

	Waterpoints			Households		
	Yes, all hh's	Mixed Yes/No	No, all hh's	Number hh Visits	Number of hh: Limits	% of hh's facing Limits
DG	3	3	5	25	11	44
KA	11	7	3	52	36	69
LL	n/a	n/a	n/a	0	n/a	n/a
NG	0	0	1	1	0	0
NH	2	3	30	75	6	8
SM	1	0	0	1	1	100

Table 12b: Limits where Permission Required, S99

	Waterpoints			Households		
	Yes, all hh's	Mixed Yes/No	No, all hh's	Number hh Visits	Number of hh: Limits	% of hh's facing Limits
DG	4	4	5	32	13	41
KA	9	3	1	35	23	66
LL	n/a	n/a	n/a	0	n/a	n/a
NG	0	0	2	2	0	0
NH	2	2	39	68	4	6
SM	0	0	3	3	0	0

Table 13a: Exchanges where Permission Required, S92

	Waterpoints			Households		
	Yes, all hh's	Mixed Yes/No	No, all hh's	Number hh Visits	Number of hh: Gave Something	% of hh's that Gave
DG	11	0	0	25	25	100
KA	6	5	10	52	18	35
LL	n/a	n/a	n/a	0	n/a	n/a
NG	1	0	0	1	1	100
NH	1	1	33	75	2	3
SM	1	0	0	1	1	100

Table 13b: Exchanges where Permission Required, S99

	Waterpoints			Households		
	Yes, all hh's	Mixed Yes/No	No, all hh's	Number hh Visits	Number of hh: Gave Something	% of hh's that Gave
DG	13	0	0	32	32	100
KA	5	2	6	35	8	23
LL	n/a	n/a	n/a	0	n/a	n/a
NG	1	0	1	2	1	50
NH	4	0	39	68	5	7
SM	1	0	2	3	1	33

As with base camp mobility, the majority of cases where people gave something to access water points occurred in DG (100% of the people gave at 11 of 15 total waterpoints) and KA (33% of the people gave at 11 of 21 waterpoints) in 1992. In NH, exchanges occurred at 4 of 43 waterpoints. In DG, all households gave something to access waterpoints at S99 and S92 points, mirroring the B92 and B99 observations.

The number of waterpoints with limits in DG is greater at S99 vs. S92 points; the two additional points appearing in 1999 both imposed limits on at least some households. However, more households went to waterpoints without limits, so that the percentage of households at waterpoints with limits was in fact lower for S99 vs. S92. In KA, though there were fewer total waterpoints with limits for S99 vs. S92, a larger percentage of these waterpoints were visited by households. As in DG, a slightly lower percentage of households visited waterpoints with limits.

The total number of waterpoints where at least some households gave something to access the point remains unchanged between S99 and S92 (26). Nonetheless, the percentage of households actually exchanging something to access waterpoints increases slightly from 31 to 34%; the percentage remains the same in DG (100%), decreases in KA (from 35 to 23%), and increases in NH (from 3 to 7%). It is interesting to note that the same total number of households gave something in both S92 and S99 (47); the difference largely stems from the fact that the total number of household visits to points where permission was required decreased from S92 to S99. Basically exchanges remained at the same level in S99 compared to S92, even though the total number of visits increased and visits requiring permission declined in percentage terms.

As with the B92 data, access to waterpoints can be characterized as essentially complete in NG, SM, and LL, and to a lesser extent, NH, where permission is required of at least some households, but only a few waterpoints impose limits or require exchanges. It is only in KA and DG where access can be characterized as incomplete, costly for some members, and where degree of access and completeness of rights differs among households accessing the same waterpoint. Waterpoints accessed by households in KA and DG differ themselves in a rather interesting way. In DG, access is basically costly for all households at waterpoints that require permission, but only about half face limits; whereas in KA, exchanges to access the waterpoints is much more limited, but a much higher percentage of households face limits. Finally, it appears that both exchanges and limits are more frequent at waterpoints used as satellite points.

Summary of Permission, Exchanges and Limits:

By simply looking at the descriptive statistics, there is very little in the way of general conclusions. The main large differences are in the total number of points used and in the total number of points visited by households, across camp types and across years. That is, more points are used for satellite camp vs. base camp, 204 vs. 107 for 1992, and 202 vs. 114 for 1999. And, though the total number of points accessed is only slightly larger for 1999 (316 vs. 311), the total number of household visits increases in 1999 vs. 1992 (893 visits vs. 743). In fact, the total number of visits to different satellite camp points is approximately the same in both years; the difference in visits per year stem largely from many more points visited for base camps in 1999.

Of the three areas where permission, exchanges and limits are important, we find that these transaction costs increase both for base and satellite camps in NH, and decrease for both base and satellite camps in DG. Households located in the KA area face higher transactions costs at base camp as expected, but lower costs in satellite camp movements. These results are roughly consistent with our main hypothesis regarding how flexible access rules operate. Nonetheless, the change across years is rather limited except for DG. However, the fact that at least some waterpoints in NH, DG and KA discriminated among households in terms of permission, exchange and limits also suggests that access may be contingent. Overall, then, there is more evidence to suggest that rights are incomplete – irrespective of the "state of the world"— and limited evidence to suggest that they are contingent and related to spatial diversity. In table 14 below, we present transaction costs indices for base camp, satellite camp, and total, calculated using the observations on household visits on permission, exchanges, and limits. Base and satellite camp transactions costs were simply summed to give a total transaction cost figure.

Table 14: Transactions Costs of Mobility

	Total, 1999	Satellite, 1999	Base, 1999	Total, 1992	Satellite, 1992	Base, 1992
NH	2.08	1.04	1.03	1.65	0.80	0.85
KA	2.39	1.29	1.10	2.55	1.74	0.81
LL	0.00	0.00	0.00	0.00	0.00	0.00
DG	2.79	0.79	2.00	4.42	1.82	2.60
SM	0.03	0.03	0.00	0.04	0.02	0.02
NG	0.08	0.02	0.06	0.08	0.02	0.06

Thus far, we have presented figures on NDVI values and spatial and seasonal variation in NDVI, transactions costs of mobility and actual mobility undertaken by households in the 1991-1992 drought year and the 1999-2000 "normal" year. We have hypothesized that transactions costs of access would be higher in regions that experienced less spatial and seasonal variation; data is roughly consistent, though measured transactions costs were not important in three (LL, SM and NG) of the six communities. We now need to relate these indicators back to waterpoint usage by households. In Table 15, the first two columns are the differences in total waterpoint and satellite camp visits, which is simply the total observed at the community level in 1999 minus 1992. Given that cropping and other activities may be important drivers in base camp movements, we separately consider satellite movements as we believe these will mirror more closely changes in agro-climatic conditions. We also calculated the difference between satellite waterpoint visits in 1999 minus those in 1992 for each household, and report the average difference across communities; this variable allows us to separate household-fixed effects from weather pattern effects better than the total waterpoint visit variable does. In the fourth column, we give the percentage change in rainfall in 1999 vs. 1992. To aid interpretation, in the fifth column we report the percentage change in spatial variability, where spatial variability is captured by the negative of the 9 category contagion index (recalling that the contagion index increases as patchiness decreases). The sixth column gives the percentage change in seasonal variability as defined above. The final column gives percent changes in satellite transactions costs; changes in total and satellite transactions costs have the same sign, so we report only satellite costs here.

Table 15: Changes between 1999 and 1992

	Absolute Change, 1999-1992			**%Change, 1999:1992**			
	Total Water Point Visits	**Total Satellite Visits**	**Avg. of HH-Level Satellite Visits**	**NDVI, 40 km**	**Spatial Variability (-CONT9)**	**NDVI CV (Seasonal variability)**	**Satellite Transactions Costs**
NH	-3	-17	-0.53	2	-17	-8	26
KA	61	-1	-0.07	7	-23	-1	-6
LL	77	31	1.03	17	36	5	0
DG	7	4	0.13	15	15	22	-37
SM	7	0	0.06	11	10	-13	-27
NG	29	-6	-0.2	8	-11	-27	1.3

As noted above, NDVI increases in all villages in 1999 vs. 1992; total visits increases in all communities as well, except North Horr, which had the second lowest percentage increase vis-à-vis 1992. Spatial variability is nearly perfectly correlated with total satellite visits; in all three areas with lower spatial variability, both the change in community level visits and per household satellite visits decrease. For the two communities with large positive changes in spatial variability, total satellite visits increase. In SM, there was no or very slight decrease in satellite visits, but an increase in spatial variability.

Changes in seasonal and spatial variability have the same sign in five of six areas; in SM spatial variability increases very slightly, but seasonal variability decreases quite a bit. Also, in NG, spatial variability is virtually unchanged, but seasonal variability decreases substantially; total water point visits actually increase in NG, but satellite visits decline slightly, more closely following the small declines in spatial variability rather than the large decline in seasonal variability. On the other hand, the seasonal variability declines only slightly compared to changes in spatial variability in KA, more closely in line with the slight decrease in satellite visits there.

Changes in satellite transactions costs, which we also expect to be influenced by spatial variability appear well-correlated with changes in spatial and seasonal variability, with the exception of KA. Transactions costs increase where spatial and seasonal variability decrease in NH and NG, and decrease in DG, where spatial and seasonal variability increase. It is worth emphasizing that there are few transactions costs in NG, SM and none in LL, so changes in transactions costs there do not provide much information. Of the three areas with significant transactions costs, then, changes in transactions costs coincide with predictions in two of three cases, with KA being the exception.

4. Estimation Results

In this section, we estimate mobility equations, where the dependent variable is the number of visits by a household to different waterpoints, separately for base camp and satellite camp herds. Estimations are for 1999 only, as household-level data was available only for that year.

Mobility is hypothesized to be a function of household-specific variables as well as the community-wide climatic conditions or transactions costs described above. Household-level variables include the age of the household head (age), the number of males in the household over the age of 14 ($males14$), the number of large ruminants (cattle and camel) managed by the herder $lrum$, the number of small ruminants (goats and sheep) managed by the herder $srum$, the proportion of the total flock that is owned by the herder $PropHerdOwn$, a measure of assets held by the household $(Assets)$, and whether or not the herder owns any cropland ($cropyn$). Age of the household head may proxy two offsetting influences; older herders may know more about the geographical distribution of resources as well as have more personal contacts in neighboring encampments, which should increase mobility. On the other hand, long-distance herding is most often undertaken by younger males. As the herder gets older and becomes less mobile himself, there are increased costs and risks associated with the long-distance movements that he no longer undertakes directly. This may reduce mobility. In the regressions, we use age and age squared ($agesq$) to allow for possible non-linear effects. Also, as just noted, younger males over the age of 14 tend to be the actual herders, particularly for longer distance movements. Thus, we include a variable for the number of males (besides the household head, if male) over the age of 14 to capture the amount of available family labor.

To the extent that there are economies of scale in herding, we expect that larger herd sizes will increase mobility and thus the use of waterpoints. However, these economies may well differ depending on the type of animal being herded. Thus, we include variables for both large ruminants and small ruminants. Given that the decision on how many large and small ruminants to hold may well be endogenous to the mobility decision, we test for statistical exogeneity between the mobility and stockholding decisions. Instruments for large and small ruminant holdings include a dummy for whether or not the household head is female (*Gender HH Head (1=Male))*, where it is expected that female-headed households are less likely to hold larger herds both because, given societal norms, females are likely to have less experience with the full range of activities associated animal production (though, clearly, they are likely to have experience with milking), and because such households are likely to be less wealthy (Smith et al., 2001). The number of children living outside of the community, *kidaway*, is hypothesized to increase herd sizes, on the assumption that migrants increase the wealth of the household. Human capital variables, such as the number of adults in the family (*phh*), the education level of the household head (*eduhead*), and an index capturing the years of education of other adults in the household (*eduhh*), are all hypothesized to increase herd sizes. Tests of exogeneity, following the standard Durbin–Wu–Hausman procedure, generally led us to not reject statistical exogeneity, but the instruments performed fairly poor, as well. Thus, regression results reported below include both the $lrum$, $srum$ specification, and a specification including only the instruments.

Next, to the extent that herding contracts suffer from moral hazard and/or adverse selection problems, we would expect that mobility would be a positive function of the proportion of the total herd managed that is actually owned by the herder. Household assets, such as the number of small shops and additional houses located in towns owned by the household, number of bicycles and radios owned, the number of consumer durables such as beds, tables, etc., and a dummy for whether or not a household has a bank account, may either have a positive or negative impact on mobility. On the one hand, greater wealth may enable the household to negotiate and enforce herding arrangements that reduce moral hazard; by credibly threatening to monitor and punish poor herding, for instance. On the other hand, more assets may increase the productivity of household labor in a wide variety of activities, potentially raising the relative opportunity costs of engaging in mobility.

Finally, we include a dummy for whether or not the household "owns" (has usufruct rights over) cropland. To the extent that cropping increases the costs of remaining sedentary – particularly for base camp herds that tend to be in closer proximity to cropland – we expect that this will increase mobility. On the other hand, like household assets, cropping may increase the opportunity costs of labor; also, crop residues may partially substitute for grazing. The impact of this variable is thus ambiguous.

Community-level climate variables include the measure of contagion index using 9 categories ($cont9$), the measure of seasonal variability captured by the coefficient of variation of NDVI values through the year ($NDVI\ CV$), and a variable capturing NDVI in 1999 relative to the long-term average NDVI ($Rel-NDVI$). We also present results for a second specification, where we use the transaction costs variable in place of the climate variables, (TCb,s), where *b* refers to base camp transactions costs and *s* refers to satellite transactions costs. By using this community-level indicator of transactions costs across possible waterpoints, we implicitly assume that the individual household cannot influence whether or not permission, exchanges and/or limits occur at any one waterpoint. In other words, the aggregate index of transactions costs within is intended to capture an exogenous "supply-side" cost of access within the area.

Given the nature of the data – where household level movements varied between 0 and 6, we need to consider the appropriate regression model specification. Below we report results using the Poisson regression model. We chose the Poisson regression model, as there was no evidence of over-dispersion and little evidence of "excess zeros"[7].

[7] We tested the hypothesis that the dispersion parameter, alpha, calculated for a negative binomial regression for both satellite and base camp movements equals zero (meaning that the Poisson is the correct model), and in all cases, we fail to reject the hypothesis that alpha=0. We were also concerned about possible "excess zero" values. However, for base camp movements, 11% of households did not engage in mobility; if households were spread evenly over the 7 categories, this figure would be 14%; so there is no indication of excess zeros. For satellite camp, 18% of households were not mobility, which also gives little indication of excess zeros. Therfore, we present results for the Poisson regression models.

Table 16-17 gives results for the four different specifications for satellite camp movements; climate vs. transactions costs specifications, with *lrum*, *srum* and separately with instruments for *lrum*, *srum*.

Table 16: Poisson Regression Results, Satellite Camp Herd Movements, 1999 (with *lrum* and *srum*)

	Satellite WP Visits			Satellite WP Visits	
	Coefficient	z-stat		Coefficient	z-stat
age	-.0344*	-2.09		-.0376*	-2.30
agesq	.00037*	2.32		.0004*	2.61
*males*14	.0403	1.11		.0501	1.20
asset	-.0588*	-2.31		-.0489**	-1.88
lrum	.0061	2.33		.0076*	3.09
srum	-.0022	-0.69		-.0046	-1.27
PropHerdOwn	-.2128	-0.93		-.3871**	-1.95
land	-.0593	-0.33		-.6821*	-6.70
$Rel-NDVI$	33.0080*	4.76			
$CoV-NDVI$	-.9612	-0.72			
*cont*9	-.0221*	-2.64			
$TC-Access$				-.3343*	-3.33
constant	-30.1977*	-4.27		2.5274*	5.98
Observations	167			167	
Wald Chi^2	160.74			125.95	
Cragg & Uhler's R^2	0.413			0.352	
Pseudo R^2	0.1248			0.1018	

* : 5% significance
**: 10% significance

Table 17: Poisson Regression Results, Satellite Camp Herd Movements, 1999 (with instruments)

	Satellite WP Visits			Satellite WP Visits	
	Coefficient	z-stat		Coefficient	z-stat
age	-.0426*	-2.51		-.0543 *	-3.09
agesq	.0004*	2.63		.0006 *	3.43
*males*14	.0395	0.87		.0246	0.51
asset	-.0729*	-2.76		-.0616 *	-2.31
PropHerdOwn	-.2347	-1.00		-.5154 *	-2.19
land	-.0766	-0.46		-.7847 *	-7.19
Rel – NDVI	38.5602 *	5.63			
CoV – NDVI	-.0560	-0.04			
*cont*9	-.0245 *	-2.83			
TC – Access				-.3441 *	-3.12
Gender	.1312	1.15		-.0143	-0.12
phh	.0355	1.60		.0526*	2.18
eduhead	-.0343	-1.63		-.0216	-0.90
eduhh	.0026	0.17		.0096	0.55
kidaway	-.0972	-1.46		-.0587	-0.88
constant	-35.6221*	-5.13		2.9321*	6.29
Observations	165			165	
Wald Chi^2	224.03			122.85	
Cragg & Uhler's R^2	0.432			0.356	
Pseudo R^2	0.1327			0.1034	

As we can see, the specification with climate variables performs better on various goodness of fit criteria; this is expected given that climate variables differ among all communities, whereas the transactions costs differ primarily only among three of the six communities. In all specifications, mobility is higher where relative rainfall is higher – perhaps a surprise to some. Conceptually this makes sense; the greater the available resources in transit and at different destinations, the more likely it is to move. Greater spatial variability increases mobility, as we expect, but seasonal variability has little impact. When replacing the climatic variables with the transactions costs, higher transactions costs consistently lead to lower satellite camp mobility. In terms of household variables, mobility declines at an increasing rate with the age of the household head, indicating that moral hazard problems associated with labor outweigh benefits from experience. More household assets and whether or not the household engages in crop farming also lead to reduced mobility, a result consistent across specifications. Finally, larger herds of large ruminants increases mobility, but small ruminants herd size has no statistically significant impact. When replacing the large ruminants and small ruminants with instruments, we note that most variables are not significant, with the exception of household education in one specification (higher education of household adults, less mobility) and greater household labor (leading to more mobility). Interestingly, males over 14 does not increase mobility for satellite herds; whether the household head is female or whether there are children who have migrated for wage work have no effect.

Table 18 and 19 presents results for the four different specifications for base camp movements

Table 18: Regression Results, Base Camp Herd Movements, 1999 (with *lrum* and *srum*)

	Base WP Visits			Base WP Visits	
	Coefficient	z-stat		Coefficient	z-stat
age	-.0301	-1.33		-.0207	-0.91
agesq	.0003	1.39		.0002	0.94
*males*14	.0612	1.36		.0260	0.59
asset	.0156	0.75		.0083	0.38
lrum	.0085 *	2.68		.0055*	2.09
srum	-.0062	-1.39		-.0015	-0.32
PropHerdOwn	.0349	0.10		.4073	1.24
land	-.2269**	-1.67		-.3638*	-3.79
Rel – NDVI	-.7033	-0.10			
CoV – NDVI	-5.4779 *	-3.70			
*cont*9	-.0025	-0.30			
TC – Access				-.0535	-0.82
constant	2.7469	0.40		1.0786**	1.71
Observations	167			167	
Wald Chi^2	86.39			43.28	
Cragg & Uhler's R^2	0.197			0.133	
Pseudo R^2	0.0592			0.0386	

Table 19: Regression Results, Base Camp Herd Movements, 1999 (wit instruments)

	Base WP Visits			Base WP Visits	
	Coefficient	z-stat		Coefficient	z-stat
age	-.0579*	-2.70			
agesq	.0005*	2.70			
*males*14	.0544	1.14			
asset	-.0014	-0.07			
PropHerdOwn	.0875	0.28			
land	-.1563	-1.11			
Rel – NDVI	-2.3213	-0.30			
CoV – NDVI	-5.3593*	-3.64			
*cont*9	.0033	0.41			
TC – Access					
Gender	.2605*	2.38			
phh	.0324	1.41			
eduhead	-.0188	-0.94			
eduhh	-.0528*	-2.59			
kidaway	.1736*	3.15			
constant	4.6490	0.61			
Observations	165				
Wald Chi^2	130.08				
Cragg & Uhler's R^2	0.261				
Pseudo R^2	0.0818				

As with the satellite mobility equations, specifications including the climate variables generally give better goodness of fit than those including transactions costs alone. However, in these equations, relative NDVI and spatial variation – both significant in explaining satellite camp mobility – are generally insignificant. Instead, base camp mobility appears to be driven by seasonal variation. Contrary to expectations, however, greater seasonal variation appears to reduce base camp mobility. It is possible that greater seasonal variability is correlated with greater cropping, and that more cropping reduces mobility; we simply do not have community-wide cropping patterns with which to test this relationship. Transactions costs have a negative coefficient, but are never statistically significant. Household-level variables appear somewhat more important than in the satellite mobility equations. Again, age of household head reduces mobility at an increasing rate, though this impact is only statistically significant in two of the four specifications. Also similar to the satellite case is the fact that large ruminants increase mobility whereas small ruminants have a consistently negative, but never significant, impact. Mobility is greater where the household head is male and in households with children who have migrated for wage work (a proxy for household wealth), and negatively related to education of the household head (a proxy for the opportunity cost of labor of the household head).

5. Conclusion

In this paper, we have examined data on herd mobility in northern Kenya to better understand the factors promoting or inhibiting mobility during both drought and "normal" years. Basic statistics on herd movements indicate that there is indeed not much difference between the total number of waterpoints accessed in drought vs. "normal" years, but that the total number of visits to different waterpoints by households generally is greater during normal vs. drought years– substantially so in certain communities. Another difference is in the use of waterpoints by base vs. satellite camp herds. During drought years, base camp herd movements are far lower than during normal years, whereas satellite camp herd movements remain roughly constant across both drought and normal years.

A robust result is the positive effect of relative NDVI levels on both base and satellite herd movements – better relative conditions within an area increase mobility. Greater spatial variability does indeed lead to greater herd mobility for satellite herds, as evidenced both in the significant coefficient in the 1999 herd mobility equations as well as the descriptive statistics comparing 1999 with 1991-1992. Spatial variability appears to have a more limited impact on base camp mobility. On the other hand, seasonal variability has a limited impact on satellite camp mobility, but, unexpectedly, has a strong negative impact on base camp mobility. It is possible that seasonal variation in NDVI is positively correlated with the expanse of cultivated lands in the area, and to the extent that a large proportion of cultivated land limits base camp mobility, this may explain the negative sign. Higher transactions costs, here captured by the need to ask permission, face limits, or make exchanges at waterpoints within an area, always lead to lower mobility for satellite camp herds, but have no impact on base camp herd movements. Altogether, results suggest that climate variables are indeed important in explaining herd movements, but are not necessarily consistent with anectdotal evidence – and received "wisdom" – on mobility. Mobility is not necessarily higher in drought years, and indeed total mobility is little changed for three of six communities when comparing the normal vs. drought year. Furthermore, long-distance movements correlate well with difference in spatial and seasonal variability, but not with drought vs. non-drought years; in fact, satellite mobility is higher in drought years only in those communities with higher spatial and seasonal variation in NDVI. Given the dataset, it is impossible to recover the impact of mobility on livestock production, but evidence presented above suggests that focusing on drought year mobility may be misleading at best. Mobility is reduced when spatial and seasonal variability is very low, which does not necessarily correspond to drought years. Further analysis determining the relationship between conflicts and spatial and seasonal variability, as well as herd productivity and variability is required, particularly given the fact that many researchers and policymakers are overwhelmingly preoccupied with mobility in drought years only, based on anecdotes alone.

With respect to household level variables, the number of large ruminants held by the household leads to greater mobility, indicating that there may be economies of scale in mobility for these herds. The number of small ruminants always has a negative coefficient, but is never significant. Interestingly, the number of males in the family has no statistically significant impact on herd mobility, whereas satellite mobility consistently declines at an increasing rate with the age of the household head. The latter indicates that benefits to experience are outweighed at some point, either because age makes mobility more difficult or because engaging labor for satellite herd movements becomes more likely as the household head ages, and such labor may be subject to moral hazard. The same does not hold, however, for base camp herds where the household head can more easily monitor herd condition and directly implement decisions on mobility. Assets and whether or not the household engage in cropping generally have a negative impact on mobility, indicating that alternative activities increase the opportunity costs of engaging in mobility, particularly longer distance term mobility captured by satellite herd movements. While using the same dataset, this result is in apparent contradiction to the results presented in Smith et al., 2001, who hold that cropping and other activities are undertaken mainly by those households whose herds have been decimated by drought[8]. The one-period results for 1999 rather indicate that alternative activities are relatively attractive precisely to those households with a higher asset base. In fact, the simple Pearsson correlation coefficients of household assets are negative with respect to large and small ruminant holdings, as well as herd mobility for the sample in total, though this does mask differences among communities. Still, this contradiction highlights the need to collect data across time and space, since recall data is usually only partial (in this dataset, there is recall data on mobility, but not on most of the other household-level indicators), and other supporting data, as in the Smith et al.(2001) study, is based on perceptions of various risks, with no attempt to match perceptions to either input decisions or actual outcomes.

Thus, without further information on the links between mobility and animal productivity and livestock income, it is difficult to draw more firmly policy relevant conclusions. Nonetheless, mobility seems to be quite important in this system in general, and satellite camp herd mobility appears to be more important during years of greater spatial and seasonal variability. Evidence suggests that exercising access rights to satellite camp waterpoints is relatively more costly than to base camp waterpoints, and that transactions cost generally increase when spatial and seasonal variability decrease. There is no reason to believe that there should be concerted policy efforts or programs designed to reduce these transactions costs – since such costs may indeed reflect opportunity costs of scarce resources. Instead, such a policy conclusion would require determining whether the transaction costs are "too high" in a socially optimal sense. Instead, policy efforts should focus on developing secondary markets for both substitute forages and livestock outputs in general – but not be preoccupied with drought years in particular.

[8] It is interesting to note that in the Smith et al. (2001) study, there is little evidence to support the notion that subjective assessments of climatic risk differ substantially from objective risks assessments, or even, given the capacity to mitigate and cope, how an "objective" indicator of "drought" might be developed. Perceptions of risk of drought and "rainfall contours" presented in the article do not show significant differences as captured in Figures 3a and 3b (it is not clear how rainfall contours map into incidence of drought), particularly for the case of northern Kenya) Subjective assessments appear more detailed, but rainfall data (from an unknown source) has been interpolated, as indicated in the article itself, meaning that spatial variation has been smoothed by definition!

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Appendix 1:

Figure 1: Number and Types of Waterpoints Used by Base Camp Herds

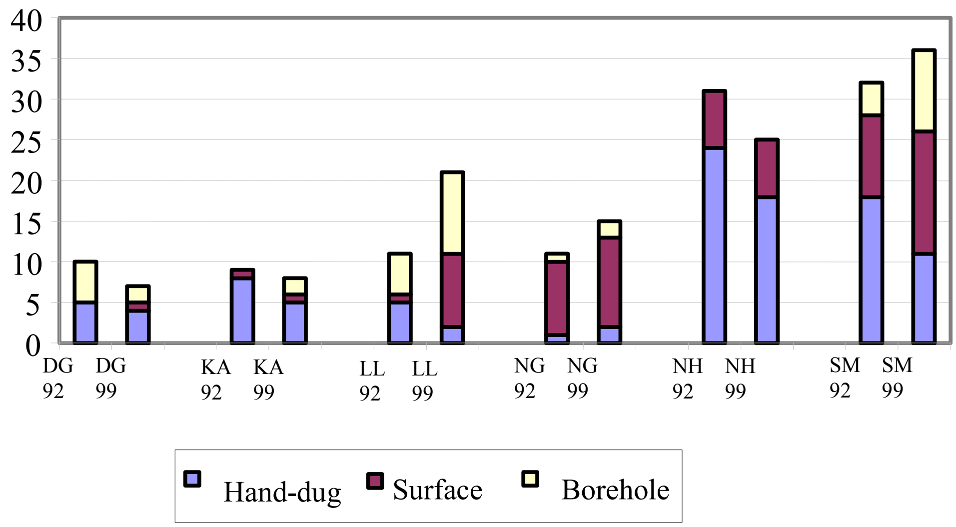

Figure 2: Number and Type of Waterpoints Used for Satellite Herds