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The Role of Livestock Mobility in the Livelihood Strategies of Rural Peoples in Semi-Arid West Africa

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Abstract Over the past 10 years, mobility of livestock has been portrayed as increasing the resilience of rural households in semi-arid Africa to climate change and variability. With this recognition, there has been important work characterizing livestock mobility and the barriers to it. This paper adds to this work by addressing two gaps in the literature: 1. An understanding in the variation of livestock mobility practices among communities; and 2. An understanding of rural peoples' views of the advantages and disadvantages of livestock mobility as well as the factors affecting their decisions about herd movements. A mixed-methods approach was adopted to analyze data collected by household survey and group interviews conducted in 32 multi-ethnic villages in Mali and Niger spanning the 12.5° N to 16.5° N latitudinal range. The results of regression and qualitative analyses show that: 1. A large fraction of rural households rely on livestock as part of their livelihood strategies; 2. Grazing management of a large majority of village livestock depends on movements outside of the village territory, especially during the rainy season; 3. The mobility of village livestock is not strongly influenced by the village's sociprofessional composition (farmer, herder, fisher, artisan..etc.); and 4. The prevalence of extra-village movements of village livestock (sheep and cattle) is higher in areas of higher population density. Despite the advantages of livestock mobility cited by informants, longer-distance movements are inhibited by risks associated with climatic, land-use, and sociopolitical change. Herd managers make decisions using diverse information about potential destinations with greater trust of information gathered by themselves or close kin. The implications of these findings for livestock management and policy in the region are discussed.

Keywords Agropastoralism · Climate variability · Sahel · Vulnerability

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Introduction

Arid and semi-arid regions of Africa have consistently been identified as among the most vulnerable regions of the world with respect to climate change (Millennium Ecosystem Assessment 2005; Ericksen *et al.* 2012). In aggregate, they are also some of the poorest areas of the world raising doubts about their capacity to manage increased climatic variability. At the levels of rural households and communities, strategies to reduce vulnerability to climate change have four components: livelihood/economic diversification, mobility, wealth stores, and technological innovation (Agrawal 2008). It has been argued that mobile livestock husbandry, a long-term adaptation to climate variability, should continue to play an important part of the livelihood strategies of the rural poor (Amanor 1995; Niamir-Fuller 1999; Thébaud and Batterbury 2001; McCarthy and Di Gregorio 2007; Adriansen 2008; Pedersen and Benjaminsen 2008). These arguments emphasize the importance of livestock

as a store of wealth; the higher resilience of more mobile forms of livestock husbandry compared to crop agriculture to climatic variability; and the increased reliance on livestock husbandry by agriculturalists (diversification). Other studies however point to growing constraints to livestock husbandry—particularly more mobile forms of livestock husbandry—due to the expansion of crop agriculture and diversion of labor from herding (Fernandez-Gimenez and Le Febre 2006; Galvin *et al.* 2008; Hobbs *et al.* 2008; Turner and Hiernaux 2008).

A number of studies have documented how herders think about herding and the benefits and costs of livestock mobility (Turner 1999; Ayantunde *et al.* 2000; Coppolillo 2000; Fernandez-Gimenez 2000; Adriansen 2008; Burnsilver *et al.* 2008; Butt 2010; Moritz *et al.* 2010; Behnke *et al.* 2011). These studies, working with small groups of key informants, have provided very important insights into the multiple factors that shape herders' decisions about pasture destinations. Moreover, they have provided much-needed empirical understandings of the spatiotemporal dimensions of livestock mobility. Still there remains a significant need for multi-site studies that document the diversity of practices and understandings of livestock investment and management in relation to livelihood responses to climatic variability (Thornton *et al.* 2009). We report here the results of individual and small-group surveys conducted across 32 villages in the Sahelian zone of Mali and Niger. These surveys are focused on the importance of livestock in household livelihood strategies, the reliance on and perceptions of livestock mobility by livestock managers and owners; the information needs for making herd movements; and the appropriate sources of such information. Understanding geographical patterns of the livestock mobility and perceived opportunities and constraints to mobility is critical for developing interventions that seek to assist household-level adaptation to increasing climatic variability.

Livestock and Livelihood Strategies in Sahelian West Africa

Livestock husbandry has historically played an important role in the economies of Sahelian West Africa (Doutressoulle 1947; Baier 1980; Smith 1992). Ethnic identity in Sahelian West Africa has long been associated with occupation with particular ethnicities associated with more mobile forms of herding being the FulBe, Kel Tamashek and Maures (Gallais 1962; Horowitz 1972; Grayzel 1977). Even within these ethnicities, certain subgroups have been seen as tied to the herding profession, herding their livestock as well as livestock owned by elites within and outside of their ethnic group (Ba and Daget 1984; Kintz 1985; Bonfiglioli 1988). Livestock ownership expanded across the rural population with the erosion of slavery during the early 20th century with various entrustment arrangements developing for the grazing management of livestock owned by non-herding groups (Turner 1993).

The expansion of livestock ownership across ethnicities and caste groups intensified since the droughts of the early 1970s with the growth of livestock ownership among farming and artisanal groups and the growing reliance on farming by pastoralists (Toulmin 1983; Mortimore 1989; Bonfiglioli 1990; White 1990). During periods of recurrent drought such as that experienced in the Sahel since the early 1970s, livestock has advantages over crop farming due to lower production risk because livestock can be moved to where rainfall occurs. The growing convergence of a mixed farming and livestock strategy can be seen, along with the increased reliance of labor emigration, as a livelihood diversification strategy by those with farming and herding identities. There remains little work in the Sahel that documents the variation in the mix of strategies relied upon by the rural households and how in particular, people assess the benefits and limitations, of more mobile forms of livestock husbandry.

Livestock Mobility in the Sahel

The Sudano-Sahelian region of West Africa experiences a monsoonal climate with distinct rainy and dry seasons. As shown in Fig. 1, annual rainfall declines (from approximately 600 to 100 mm annual average) and the rainy season shrinks within the May to November period (from 6 months to less than 1 month) as one moves south to north along the 12.5 and 20° north latitudinal gradient. Herbaceous vegetation is dominated by annual grasses and forbs (dicots) with significant spatiotemporal heterogeneity of palatable forage.

Two major biophysical forces shape the movements of livestock in the region: 1. the high local spatiotemporal variability of rainfall and resulting vegetative growth; and 2. the more predictable movement of the south-to-north green-up and north-to-south senescence of vegetation at a regional level with greater forage quality in the dryer north (Penning de Vries and Djitèye 1982; Le Houérou 1989; Butt *et al.* 2011). Simply put, three general categories of livestock management can be identified with respect to livestock mobility:

1. Village-based management of two types. A. Village-based management of small numbers of livestock kept at the homestead with food brought to them by their managers (Amanor 1995; Turner and Hiernaux 2008). This management mode is usually performed to fatten a small number of sheep or goats for subsequent sale, for a small dairy herd, or for sick or wounded animals. While this mode is important economically, only a very small fraction of the regional livestock population is managed in this manner. B. Village-based management with dispersion (Faugère *et al.* 1993; Schlecht *et al.* 2004; Turner and Hiernaux 2008). Livestock are kept within the village territory dispersing to the edge of the village's cultivated

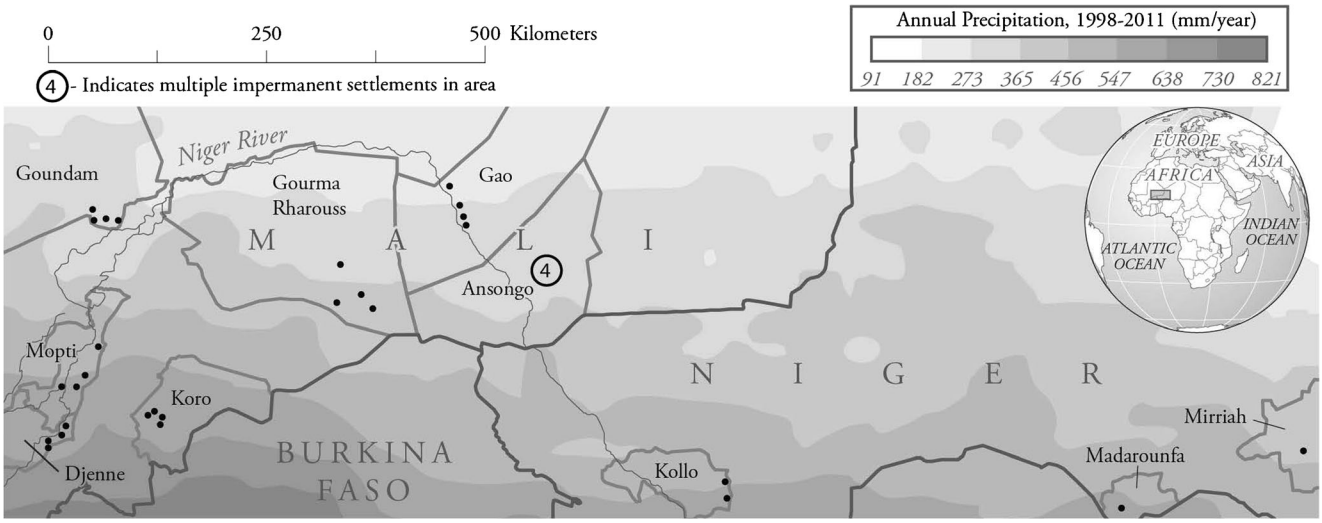

Fig. 1 Map of the study villages (*dark circles*) within ten administrative districts in Mali and Niger with background *shading* of mean annual rainfall over 1998–2011 period as adapted from map generated by NASA GIOVANNI (http://gdata1.sci.gsfc.nasa.gov/ daacbin/G3/gui.cgi?instance_id=TRMM_3B42_Daily) as estimated from TRMM_3B42_daily.006 data

area or other lands associated with the village. This type of management is often referred to as sedentary management.

2. Proximate encampment. Livestock are moved a relatively short distance (within 40 km) to an encampment outside of the village territory to access pastures, markets and/or water during some portion of the year (Bassett 1986; Hellemans and Compere 1990; Lericollais and Faye 1994; de Bruijn and van Djik 1995; Adriansen 2008). Such movements are driven by the high spatiotemporal variability of rainfall (biophysical factor #1 above) and possibly by high cultivation pressure (reducing local pasture area).
3. Distant encampment. Longer-distance seasonal herd movements (>40 km), referred to as "transhumance", connect areas to the south with those of the north and/or rainfed areas with floodplain areas (Beauvilain 1977; Breman *et al.* 1978; Benoit 1979; Turner 1999; Bassett and Turner 2007). Such seasonal movements are driven by the higher forage quality during the rainy season to the north / uncultivated zone (biophysical factor #2 above) and greater availability of water to the south or in the floodplain area during the dry season. On a regional level such movements result in greater numbers of livestock in the northern portion of the study region during the rainy season and greater numbers in the south and on floodplains during the dry season. Those herd managers with homes in the south and who practice transhumance will move their herds to the north with the rains and remain there until surface water bodies dry at the beginning of the dry season. Those herd managers in the north are more likely to remain in the north during the rainy season, and may lead their animals to the south or to floodplain pastures during the dry season.

Grazing management of the vast majority of livestock in the region involve different combinations of these modes during different seasons of the year. Studies have shown that herd movements outside of the village territory (modes 2 and 3) are not random (Bassett 1986; de Bruijn and van Djik 1995; Niamir-Fuller 1999; Bassett and Turner 2007; Adriansen 2008). Herders rely on well-defined encampment points along livestock corridors (paths) to which they have access. It is from these encampment points that livestock disperse to graze and where unweaned calves are kept separate from their mothers to allow milking. Due to the spatiotemporal variability of rainfall (biophysical factor #1 above), the timing of herd movements and the particular corridor and encampment options herd managers choose will vary from year to year.

After years of policy and scholarly neglect (e.g. Sinclair and Fryxell 1985), more mobile forms of livestock husbandry are now recognized as an important means to reduce vulnerability to drought and to limit the negative ecological effects of livestock grazing in open rangeland situations (Sandford 1982; Behnke *et al.* 1993; Scoones 1994; Niamir-Fuller 1999; Turner *et al.* 2005; Adriansen 2008). At the same time, concerns have been raised about the labor and social costs of livestock mobility as well as about its long-term viability with the expansion of cultivated area, the blocking of livestock corridors, growing social conflict and insecurity, and shifts in livestock ownership from herding professionals to others without the necessary and social contacts required in moving herds (Lericollais and Faye 1994; Raynaut and Lavigne Delville 1997; Moritz 2006; Turner and Hiernaux 2008; Turner 2009).

There is a need for empirical studies not only of the variation in livestock mobility in the region but of local understandings of its benefits, risks, and requirements. This

Table 1 The major ethnic groups and population density of the administrative districts in Mali (Cercles) and Niger (Départements) where study villages are located. The number of study villages found within the administrative district is given along with whether these villages have access to the Niger River floodplain which allows for irrigated agriculture and fishing

Administrative district	Major ethnic groups	# of study villages	Pop density[a] (#/km^2)	Access to Niger River
Mali				
Ansongo	Kel Tamashek	4	6	No
Djenne	Bambara, Soninke, FulBe	4	45	Yes
Gao	Sonrhai/FulBe, Kel Tamashek	4	8	Yes
Goundam	Sonrhai, Bozo, Kel Tamashek, FulBe	4	8	Yes
Gourma Rharous	Sonrhai, Kel Tamashek	4	3	No
Koro	Dogon, FulBe	4	33	No
Mopti	RimayBe, Bambara/FulBe	4	51	Yes
Niger				
Kollo	Djerma, FulBe	2	44	No
Madarounfa	Haussa, FulBe	1	162	No
Mirriah	Haussa, FulBe	1	75	No

[a] Based on the 2009 census in Mali and the 2011 population estimates (last national census in 2001) in Niger

paper presents the findings of an extensive survey on these topics across 32 villages in Mali and Niger.

Methods

A common set of surveys were administered in four villages in Niger between 7/1/2007 and 12/1/2007 and 28 villages in Mali between 6/1/2009 and 10/1/2009 (Fig. 1). These villages cover a latitudinal range of 12.5° N to 16.5° N and a longitudinal range of 4.3° W to 9.1° E and are found in seven administrative districts (cercles) in Mali and three administrative districts (départements) in Niger (see Fig. 1). These districts have experienced different levels of rainfall over the past 14 years (Fig. 1). Moreover, they experience quite different levels of population pressure, the variation of which is influence but not determined by latitude and mean rainfall (Table 1). Members of all villages have different ethnic identities (Table 1) and are variously involved in a mix of livelihood activities described above including farming, livestock husbandry, and labor emigration. Some villages found within the four cercles of Mali have access to the Niger River and therefore floodplain agriculture and fishing are livelihood options (Table 1). Surveys were administered by ten different but commonly-trained research assistants (one per administrative district).

Data Collection

Basic demographic, social identity, livelihood, and livestock ownership data were collected through a combination of group and household-level interviews in each of the 32 study villages. Initial group interviews of village leaders (headed by the village chief) were conducted to identify the principal socio-professional groups (ethnicities and castes) who hold different social and occupational identities (artisan, fisher, hunter, herder, farmer) within the village. These groups were ranked with respect to land control and livestock ownership. A list of all households within the village was developed with each categorized with respect to socio-professional identity. The household heads of a subsample of all households were surveyed to characterize the household's livelihood strategy portfolio (livestock, crop agriculture and labor emigration). We will use this information to characterize communities by the degree to which people place herding livestock as their most important livelihood strategy.

Within each village, interviews of two groups of 5–6 informants were conducted on the mobility of village livestock. In some cases, the first group was composed of older men of mixed socio-professional identity who were managers or owners of livestock and the second group was composed of younger men who were actively involved in the management of livestock grazing (with a strictly herding socio-professional identity). Enumerators were not always consistent in applying the age differences as a way to group respondents so we end with some groups clearly composed of older herders, those composed of younger herders, and those where respondents are of mixed ages.[1]

In these interviews, informants were asked to characterize the percentage of village livestock remaining in the village territory, outside of village territory but within 40 kilometers

[1] Subsequent statistical analysis reveals no difference in the estimates of mobility for village livestock provided by older and younger respondents.

(kms), and outside of the village territory and farther than 40 kms during both the cropping / rainy season and the non-cropping / dry season. For each village, landmarks 40 kms away in different directions were referred to in order determine whether those livestock leaving the village territory travelled farther than 40 km. Informants were asked to identify the major pasture destinations outside of the village territory (up to two) during the rainy and dry seasons, and the routes to each were described by listing the encampment points visited along the way. Informants were asked to describe any problems that exist along the path between successive encampments. Through a series of questions, informants were also asked their opinions about livestock mobility, changing opportunities and constraints to livestock movements, and the information needs associated with them. These questions covered the following topics:

1. The advantages and disadvantages of sending livestock outside of the village territory during the rainy and dry seasons
2. The most important changes affecting their access to pasture and water and how these have affected their livestock movement decisions
3. The types of information that is either absolutely necessary or simply beneficial for making decisions concerning the timing and destination of livestock movements during the rainy and dry seasons.
4. The degree to which previous conflicts influence livestock movement decisions.
5. The primary sources of information that they use to make herd movement decisions
6. The usefulness of rainfall predictions such as those broadcast on the radio

These questions were asked in an open-ended fashion with research assistants matching responses to a list of response categories on the survey form. When a response did not match a category, research assistants were asked to create a new response category. Once all responses from the group were enumerated, informants were asked to rank them in terms of their importance. Ranked data were normalized to rank scores ranging from 0 to 1 as described in Smith *et al.* (2001), with all responses not mentioned by informants assigned a value of zero.[2] Results are presented as simple means (rank scores) and counts by administrative district. In some cases, the responses as paraphrased in research assistants' notes are presented to provide fuller, more qualitative insights.

Data Analysis

A mixed methods approach was followed for analyzing the information gathered through the surveys to address two sets of questions. The first is to characterize the geographic variation in livestock mobility observed and to identify the factors that explain any variation. For dependent variables, we use the percentage, as reported in the group interviews, of the village's cattle, sheep and goats during the rainy and dry seasons in each one of three grazing zones (call the zones z): within the village territory (generally within a radius of 5–6 km from village center) or outside the village territory at a destination less than or greater than 40 km from the village. Thus for each species s, there are 6 total regressions, three per season for each of the three different zones.

Independent variables used in the regression analysis are described in Table 2. The fraction of village households without a herding identity (NoHerdFrac) is included to evaluate the role of ethnic/caste composition on the proclivity of communities to rely on livestock mobility. The population density (Popdens) of the local administrative district is used as a proxy for local pasture scarcity due to competing land uses (crop agriculture). The percentage of village households owning livestock of a particular species that own greater than 4 head (% large_herd$_s$) is used to evaluate the role of the prevalence of larger livestock endowments on the proclivity to invest time and labor into moving village livestock. Dummy variables corresponding to three of the four major regions (Timbuctou, Gao, Mopti in Mali and Niger) are including to control for administrative policies or cultures unique to these regions. Finally to evaluate the role of location within these regions, longitude and latitude of villages were included as independent variables.

If any community reported a 0 % or 100 % share of the herd for a migration zone, tobit estimation is used, otherwise ordinary least squares regressions (OLS) are conducted. The regression equation is as follows:

$$\%of\ herd_{zs} = \alpha + \beta_1 * NoHerdFrac + \beta_2 * NoHerdFrac^2 + \beta_3 * popdens + \beta_4 * popdens^2 + \beta_5 * Latitude + \beta_6 * Longitude + \beta_7 * Niger + \beta_8 * Gao + \beta_9 * Mopti + \beta_{10} * \%\,\text{large\_herd}_s + \varepsilon_{zs}$$

The second set of questions concern the perceptions of informants about: the benefits and costs of livestock mobility; changes in access to resources important for livestock; and factors affecting herd movement decisions. These questions are addressed through computing average rank scores of the importance of different benefits, costs, changes, and factors as well as more qualitative analysis of how herders make livestock movement decisions.

Results

The results of household surveys and group interviews conducted across the 32 villages were used to: 1. Characterize the livelihood portfolios of surveyed households (household survey); 2. Analyze the inter-village variation of seasonal

[2] Ordinal ranks are normalized using the formula $1-\frac{(rank-1)}{Number\ of\ items\ ranked}$

Table 2 Description of the independent variables used in regressions analysis of the percentage of village livestock moving to different zones (village territory, less than 40 km from village, and greater than 40 km from village) during the rainy and dry seasons

Independent variable	Description
NoHerdFrac	Fraction of surveyed households within the village without a herding socioprofessional identify. The vast majority of these cite their major occupation as farming but fisherfolk and artisinal groups are also included.
Popdens	The population density of the local administrative district (cercle in Mali, département in Niger) in persons/km^2
Longitude	Longitude east (−) or west (+) in decimal degrees
Latitude	Latitude of village in decimal degrees north of equator
Niger	1 if village is located in Niger, 0 otherwise
Gao	1 if village is located in the Gao Region of Mali, 0 otherwise
Mopti	1 if village is located in the Mopti Region of Mali, 0 otherwise
% large_herd$_s$	The percentage of the surveyed households in the village that own more than 4 of the particular species (cattle, sheep, or goats)

livestock mobility (household survey and group interviews); 3. Analyze informants' perceived advantages and disadvantages of extra-village livestock mobility (group interviews); 4. Characterize the changes in the access to pasture and water experienced by herd managers over the past decade (group interviews); and 5. Analyze factors that shape herd movement decisions as reported by informants (group interviews). These topics are addressed in the next five sections of the paper.

Village Livelihood Characteristics

Table 3 presents characteristics of the livelihood strategies of the surveyed households within the ten administrative districts. The data presented are divided by those who self-identify themselves as herders and those who are more tied to farming as a profession. While there is significant variation from district to district, a number of conclusions can be drawn from these data. "Farmers" and "herders" are involved in livelihood activities that transcend their professional identities. A very high fraction of respondents, no matter their professional identity, are involved in some way with farming. While "herders" generally show higher rates of livestock ownership, a majority of all households own livestock. Only in the case of the administrative districts of Gao, Goundam, and Gourma-Rharous do the majority of "farmers" not own livestock. In all cases, "herders" have significantly higher rates of cattle ownership than "farmers." Fourth, the participation in labor emigration is much more variable than cropping and livestock husbandry. In general, "herders" have lower rates of labor emigration than "farmers". This may be due to the year-long labor demands of herding compared to rain-fed cropping.

Livestock Mobility of Village Livestock

Table 4 provides an overview of our findings on livestock mobility. One clear pattern is that almost three quarters of village livestock (70 % on average across species) moves out of the village territory during the rainy season while around half (51 % on average across species) moves into the village territory during the dry season. This pattern is largely produced by seasonal shifts in the relative importance of village-based livestock and livestock moving greater than 40 km away from the village. This finding is consistent with the historic pattern in the region where animals move out of cultivated areas during the rainy season with returns after harvests. Species-specific results show that cattle mobility is higher than small stock mobility during both seasons.

Figure 2 depicts the livestock mobility variation across the 32 study villages. As noted above, grazing management of cattle shows greater mobility than that of small ruminants with greater likelihood for livestock to be away from the home village during the rainy season. Despite this general pattern, there is significant variation from village to village and between regions with Madarounfa, Gao, Ansongo, and Mirriah districts displaying significantly lower mobility than other sites. Mobility variation is not strongly correlated with latitude and average mean rainfall. The Mopti, Djenne, and Koro districts, all south of Gao and Ansongo, are characterized by higher livestock mobility.

There are a number of reasons given for why some village livestock are not sent outside of the village territory for pasturing. First, livestock owners prefer to keep milk and weaker animals back (<=10 %). In addition, some small ruminants may be kept back to sell to provide for family needs. During the rainy season, some cattle remain for plowing. For a few cases in the north, informants stated that local pastures were sufficient for their livestock. Beyond these production and economic reasons, some stated that they preferred to keep livestock within the territory to avoid problems elsewhere over damage to cultivated fields. For small livestock owners, the financial and labor costs may not be seen as worthwhile given the small number of livestock involved. Finally, a significant fraction of farmers stated they do not trust local herders sufficiently to entrust their livestock with them in areas distant from the village territory.

Regression analysis was performed to understand the factors that contribute to inter-village variation in livestock mobility. Tables 5 and 6 present rainy and dry season results respectively. In general, regression models explain more of the variation of dry season mobility. Relations were less strong for

Table 3 Livelihood characteristics of sampled households within the 32 study villages for each of ten administrative districts of Mali and Niger. The total number of households within the study villages (# of households) and the percentage of these households included in the livelihood survey (sampling %) are presented. Sampled households are divided by their socioprofessional identity between "herding" (which includes households that define themselves as herders or herder-farmers) and "other" (which includes households that define themselves as farmers, farmer-fishers, farmer-foresters, and artisanal). The percentage of all households that fall into these categories is presented. For each category, the percentages of surveyed households that: farm or own a field (% fields); have at least one member who has gone on labor emigration over previous year (%Mig); have a member that owns at least one cow (% cattle); and have a member that owns at least one small ruminant defined as sheep and goats (%SR) are presented

	Mali							Niger		
	Ansongo	Djenne	Gao	Goundam	Gourma Rharous	Koro	Mopti	Kollo	Madarounfa	Mirriah
# of households	662	310	1508	600	122	545	357	742	612	430
Sampling %	16	41	10	23	89	36	36	17	28	98
Herding households (%)	67	44	31	44	60	15	46	28	11	6
%Fields	74	98	87	72	60	100	92	98	91	100
%Mig	3	54	36	70	26	41	14	24	9	11
%Cattle	46	88	72	73	75	86	88	95	22	26
%SR	100	87	91	28	77	90	80	98	78	70
Other households (%)	33	56	69	56	40	85	54	72	89	94
%Fields	94	99	90	83	95	100	100	100	99	89
%Mig	3	68	17	91	23	45	13	85	26	26
%Cattle	51	25	17	8	7	23	24	20	11	19

goat mobility compared to sheep or cattle mobility. No consistent trends were found for the effects of different regions (Niger, Gao, Mopti) across all species except for a consistent reduction in extra-village mobility during the dry season in the Mopti Region. This most likely reflects the fact that the western portion of the Mopti region is an area of convergence of livestock during the dry season (Gallais 1984). Similarly, once controlled by region, longitude and latitude have variable effects during the rainy season. For the dry season, we see a more consistent trend, across all species, of a decrease in the prevalence of the movements outside of the village territory but within 40 km with latitude. This most likely reflects a tendency for livestock in the north to be based near settlements or waterpoints (Village) or to be in the more distant south (greater than 40 km) during the dry season. During the dry season, there was also a consistent trend, across all species, of reduced mobility with longitude (positive trend in village-based livestock and declines in movements beyond village territory). There is no simple explanation for this observation. Despite previous studies suggesting that managers with fewer livestock will be less likely to invest resources necessary for higher levels of mobility (Turner and Hiernaux 2008), regression analysis finds that the fraction of livestock-owning households owning more than four livestock has no significant effect on livestock mobility patterns except in the cases of lower and higher prevalence of cattle and sheep movements beyond 40 km of the village respectively.

Table 4 Mobility averages by species and season across the 32 study villages

Species	Mobility category	Rainy season	Dry season
Cattle	Village territory	22 %	45 %
	<40 km from village	26 %	23 %
	>40 km from village	52 %	32 %
Goats	Village territory	33 %	56 %
	<40 km from village	27 %	22 %
	>40 km from village	40 %	22 %
Sheep	Village territory	34 %	53 %
	<40 km from village	25 %	21 %
	>40 km from village	41 %	26 %

Local population density has significant effects on the prevalence of a number of different livestock mobility modes during both the rainy and dry seasons. Figure 3 shows the significant relationships of population density with mobility patterns revealed through regression analysis. Population density was a significant independent variable for ten of the 18 zone-species-season combinations at the $p<0.05$ level of significance. Generally, more significant relationships were found during the dry season compared to the rainy season. This is likely due to the fact that extra-village mobility is high during the rainy season across all study villages (Table 3). Mobility tends to increase with increases in population density. During the rainy and dry seasons, cattle movements beyond 40 kms dominate at population densities greater than 25 persons/km^2 with most cattle managed in the other two zones (village, less than 40 km) at population densities less than

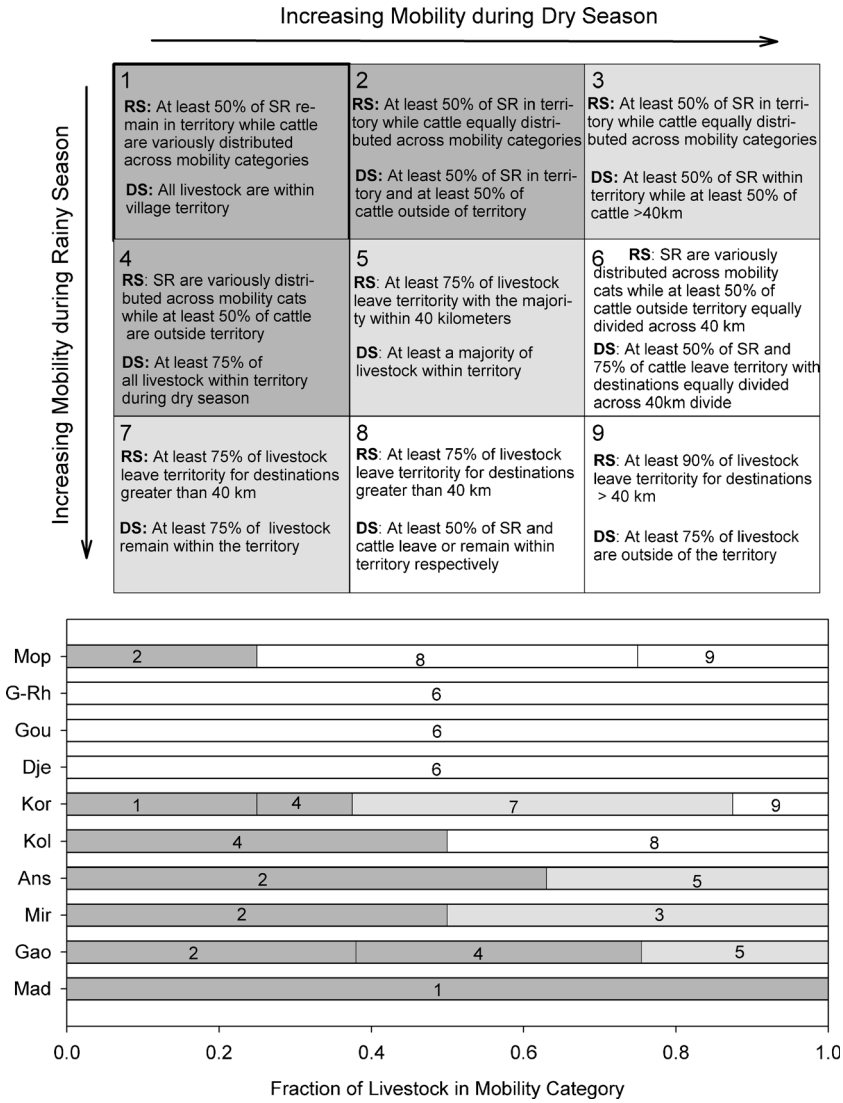

Fig. 2 Matrix of nine livestock mobility categories generated from surveys of herd mobility at the 32 study villages with increasing levels of mobility during the rainy (RS) and dry (DS) seasons increasing downward and to the right respectively. Categories of high mobility (6, 8 and 9), intermediate mobility (3,5,7) and low mobility (1,2,4) are *unshaded*, *light and dark shaded* respectively. The fractions of the interviews characterizing livestock mobility that fall into mobility categories are presented for each administrative district as *horizontal bar* graphs. The administrative districts are: Mopti (Mop), Gourma-Rharous (G-Rh), Goundam (Gou), Djenné (Dje), Koro (Kor), Kollo (Kol), Ansongo (Ans), Mirriah (Mir), Gao, and Madarounfa (Mad)

these thresholds. During the dry season, sheep movements beyond 40 kms dominate at population densities greater than 80 persons/km^2 while for goats, extra-village movements (<40kms, >40kms) dominate above 120 persons/km^2 while village-based management dominates below 100 persons/km^2.

The fraction of village households that do not have herding socioprofessional identities (NoHerdFrac) are found to have fewer significant effects on the livestock mobility patterns than population density. During the rainy and dry seasons, only 0 and 3 of the nine zone-species combinations are significant at the $p<0.05$ level respectively. During the dry season, cattle and goat movements beyond 40 kms decline gradually with NoHerdFrac. The prevalence of village-based goats remains high throughout the range, increasing gradually above NoHerdFrac values of 0.5. These findings support the conclusion that socioprofessional composition of villages does little to explain the variation in livestock mobility observed—especially during the rainy season.

Advantages and Disadvantages of Extra-Village Livestock Mobility

When asked about the advantages and disadvantages of sending livestock outside of the village territory, the 64 groups of respondents provided a range of responses. Table 7 lists average normalized ranks of the most commonly-stated advantages for sending livestock out of the village territory during the rainy and dry seasons. During the rainy season, providing livestock better pasture and facilitating movements to where grass has sprouted due to rain were more highly ranked as were to escape local lack of pasture due to agriculture and to avoid crop damage. During the dry season, the relative importance of avoiding cropped fields declines (although irrigated plots remain) with highest rankings given to gaining access to better pasture and water. In sum, perceived advantages of herd mobility are to better provide livestock with pasture and water and, at least during the rainy season, to avoid crop damage.

Table 5 Results of nine species-specific regression analyses on the fractions of village livestock being managed in each of three zones (village, outside of village within 40 kms, and outside of village greater than 40 kms) during the rainy (cropping) season. Coefficients for each independent variable and their level of significance are presented. For tobit regressions, goodness-of-fit measures of sigma and pseudo R^2s are presented while for OLS results, standard R^2 are presented. Joint tests of the nonlinear coefficients for the no herding fraction (NoHerdFrac), population density (Popdens) and their squares are also presented

Independent variable	Cattle			Sheep			Goats		
	Village	<40 km	>40 km	Village	<40 km	>40 km	Village	<40 km	>40 km
NoHerdFrac	−39.1	−33.3	55.8	−52.3	32.7	23.9	−138.0**	45.3	123.3**
NoHerdFrac^2	36.8	39.8	−53.0	64.7	−10.6	−47.3	124.1**	−49.9	−103.8*
Popdens	−1.2	−3.4***	3.9***	1.8	1.9	−2.6**	0.6	−0.3	−0.3
Popdens^2	0.5	1.5***	−1.7***	−0.8	−0.7	1.1**	−0.2	0.2	0.0
Longitude	1.7	7.3***	−6.5**	5.2*	0.4	−5.6**	3.3	−2.8	−1.9
Latitude	16.4*	43.5***	−47.1***	−15.8	−50.2**	41.6***	8.1	−6.1	−4.5
Niger	85.3*	172.3**	−228.7***	−127.2	−270.6**	269.6***			
Gao	−0.5	−29.6***	19.9**	21.9	7.6	−28.4**	11.3	18.9	−28.2
Mopti	73.4**	161.5***	−204.8***	−53.7	−175.2	137.8**	4.7	−29.5	9.5
% large_herd	0.2	0.7***	−0.7***	−0.5**	−0.1**	0.6***	0.0	0.0	0.0
Constant	−230.5*	−639.0***	800.9***	290.4	813.5**	−625.4***	−71.5	116.1	85.2
Sigma (tobit)		19.7***	20.6	25.7**	25.4***	22.6***	28.2 **	26.3**	27.6***
Joint NoHerdFrac	0.9	0.5	0.9	1.1	0.7	1.8	2.8*	0.5	2.3
Joint Popdens	3.1*	5.6***	9.4***	1.0	2.6*	3.6**	0.8	0.2	1.1
R^2	0.08	0.07	0.06	0.03	0.06	0.06	0.03	0.04	0.05

*** denotes significant at the 1 % level, ** significant at the 5 % level, * significant at the 10 % level

Table 6 Results of nine species-specific regression analyses on the fractions of village livestock being managed in each of three zones (village, outside of village within 40 kms, and outside of village greater than 40 kms) during the dry season. Coefficients for each independent variable and their level of significance are presented. For tobit regressions, goodness-of-fit measures of sigma and pseudo R^2s are presented while for OLS results, standard R^2 are presented. Joint tests of the nonlinear coefficients for the no herding fraction (NoHerdFrac), population density (Popdens) and their squares are also presented

Independent variable	Cattle			Sheep			Goats		
	Village	<40 km	>40 km	Village	<40 km	>40 km	Village	<40 km	>40 km
NoHerdFrac	−16.1	0.6	55.4	24.3	23.2	−5.6	0.4	18.1	5.8
NoHerdFrac^2	42.5	13.2	−98.7***	5.3	−7.8	−33.4	49.4	−36.1	−47.7
Popdens	−4.0***	−0.5	3.8***	−1.8	−0.3	1.5	1.8	−3.6***	0.4
Popdens^2	1.5***	0.5	−1.4***	0.4	0.6	−0.4	−1.6*	2.3***	0.3
Longitude	9.9***	−7.8	−10.5***	14.5**	−7.5	−13.6***	20.6	−15.6***	−12.9**
Latitude	24.5***	−52.2***	4.8	30.8	−70.5***	6.9	0.2	−25.8**	15.4
Niger	219.5***	−152.5	−99.2*	149.2	−259.7**	21.9			
Gao	15.6.5*	20.1	−7.8	15.9	18.7	−9.9	−9.2	37.1*	−3.5
Mopti	198.8***	−120.8*	−127.0***	185.4**	−160.8**	−90.7	27.3	0.4	−32.0
% large_herd	−0.1	0.2	−0.2	−0.3	−0.2	0.4*	−0.3	0.2	−0.1
Constant	−329.3**	839.7***	−69.8**	−432.0	1135.8***	−101.2	51.2	422.8**	−224.5
Sigma (tobit)	16.9***	19.72***	14.8***	31.6***	20.4***	23.1***	28.2 ***	20.5***	23.6***
Joint NoHerdFrac	2.3	0.3	6.8**	0.9	0.5	2.8*	4.6**	1.4	3.9**
Joint Popdens	25.8**	1.1	26.7***	5.9***	6.5*	4.1**	4.4 **	5.6***	4.8**
R^2	0.15	0.09	0.17	0.07	0.10	0.09	0.11	0.10	0.11

*** denotes significant at the 1 % level, ** significant at the 5 % level, * significant at the 10 % level

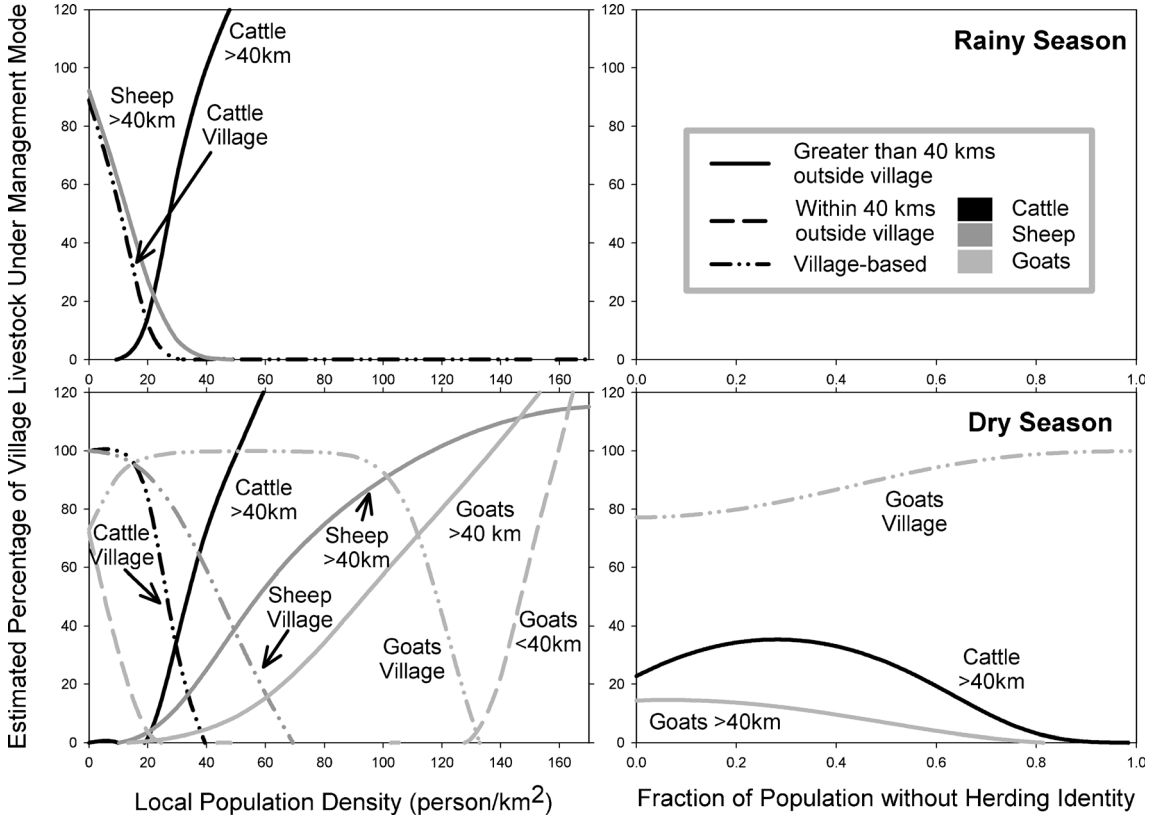

Fig. 3 Estimated percentage of the villages' livestock population (cattle, sheep, and goats) under the three different mobility modes (village-based, less than 40 km from village, and greater than 40 kilometers from village) during the rainy (*top* graphs) and dry season (*bottom* graphs) as a function of local population (*left-hand* graphs) and of the fraction of the village's households whose primary socioprofessional identity is not herding (*right-hand* graphs). These are estimates derived from regression analyses (Tables 5 and 6). Only those estimates where the independent variable (population density or nonherding identity) was found to be significant at $p<0.05$ level are presented

Table 8 lists the average normalized ranks of the most commonly stated disadvantages of sending livestock out of the village territory during the rainy and dry seasons. During the rainy season, the two most highly-ranked disadvantages are losing access to milk and other livestock products and the greater chance of problems with cropped fields and farmer-herder conflict. Interestingly, increased risk of farmer-herder conflict is presented as a disadvantage while avoiding local crop damage is seen as an advantage of leaving the village territory during the rainy season. For some villages, both are ranked highly. In others, crop damage is only seen as a disadvantage to livestock movements outside of the village territory. Both of these characterizations are most common in areas of higher agricultural pressure. Avoiding crop damage is cited as only an advantage to livestock mobility most commonly at northern sites where expansive pasture areas exist away from the village (e.g. Ansongo villages). During the dry season, the risk of not finding good pasture or water outside of the village territory and the greater energy expenditure of livestock are the two most highly-ranked disadvantages of livestock mobility.

Changing Access to Pasture and Water Resources Over Previous Decade

During the 64 interviews, 116 livestock pathways used by informants to take livestock outside of their village territories were described by listing a succession of encampment points along their length (1,359 encampments in total). Informants were asked to describe any problems for livestock husbandry between successive encampment points. Six hundred eighty-four notes were taken. These can be categorized as: 1. lack of pasture extent (19 %); 2. cropped field encroachment (14 %); 3. problems with wild animals (14 %); 4. restricted livestock passage (10 %); 5. livestock loss or disease exposure due to high concentrations of livestock (8 %); 6. government or customary authority harassment (8 %); 7. livestock theft (7 %); 8. limited water (7 %); 9. farmer/herder conflict (6 %); and 10. assorted other problems (6 %). Given that items 1, 2, 4, and 9 are related to land-use competition between farmers and herders, this is major problem area for extra-village livestock movements.

In order to learn of perceived changes in pastoral access to resources, informants were asked to describe any changes in their access to pasture and water over the past decade. Of the

Table 7 Average rank scores of advantages to movements of livestock outside of village territory during the rainy (RS) and dry (DS) seasons as recorded from 64 group interviews in the 32 sample villages

Advantage	Normalized rank scores	
	RS	DS
To gain better access to water	0.27	0.62
To gain access to better pasture elsewhere	0.56	0.60
Avoid crop damage	0.54	0.31
Escape local lack of pasture due to agriculture	0.52	0.34
Facilitate flexible movements to places where grass has sprouted due to rain	0.45	–
Avoid animal diseases	0.30	0.29
To gain more access to milk and livestock markets	0.21	0.18
To gain better access to nutritional supplements and/or veterinary services for livestock	0.17	0.28
To gain better access to minerals (salt licks)	0.16	0.33
Escape the monitoring of government agents	0.09	0.11
Escape the monitoring of the elders	0.07	0.09

58 recorded responses, ten stated that there had been no significant changes. Of the remainder, only two mentioned an increase in access due to increases in rainfall. The rest described a decline in access due to one or more reasons including: the expansion of cropland area (56 %); reduction in rainfall (26 %); increased insecurity in pasture areas (22 %); fewer water points (20 %); increased resource extraction due to bush burning, hay gathering and tree cutting (19 %); a greater of influx of livestock into traditional pasture areas (15 %); and ecological decline (13 %). Informants viewed these reasons as inter-related as illustrated by these paraphrased responses:

Table 8 Average rank scores of disadvantages to movements of livestock outside of village territory during the rainy (RS) and dry (DS) seasons as recorded from 64 group interviews in the 32 sample villages

Disadvantage	Normalized rank scores	
	RS	DS
The risk of not finding good pasture or water	0.38	0.72
Greater chance for problems with fields and farmer-herder conflict	0.56	0.33
Less access to milk and other products of livestock husbandry	0.53	0.35
Less ability to sell livestock when cash is most needed	0.33	0.37
Greater chance for livestock to be lost	0.29	0.33
Greater energy expenditure by livestock	0.27	0.46
More risk of livestock theft by herders	0.24	0.29
More risk of livestock being stolen or taxed by bandits or local authorities	0.16	0.21
Requires greater amount of herding labor	0.12	0.17

There are insufficient pastures and water points due to the lack of rains. Greater concentration [of livestock] around remaining water points followed by rebel are attacks have taken the rest of our livestock.
(notes from interview in Goudam)

Over the last 10 years, our livestock do not go to the north or northeast due to the general insecurity there despite the fact that at these destinations, the rainfall has been good—there is good pasture and water and no fields.
(notes from interview in Gao)

There is a lack of space for pasture due to cropped fields. There is a diminution of forage quality due the infertility of soils. There are now many more animals because almost everyone is interested in livestock husbandry. Farmers have become herders. There is too much selling of hay. Thieves are very much present at more distant encampment points. The declines of rainfall and of the length of the rainy season have led to the disappearance of grass species and of certain trees and bushes that important as grazing resources.
(notes from interview in Kollo)

Within the village territory, livestock pasture on the livestock corridors since pasture area has become very restricted due to the invasion of fields. Animals must go long distances to pasture. There has been a loss of palatable forage species and a complete lack of pasture area near the village. Outside of the village territory, animals do not have access to pasture locations except for movement corridors themselves. This factor has reduced the benefits of departing the territory. The distances travelled to access pastures are long and challenging.
(notes from interview in Madarounfa)

We observe variation in how informants characterized rainfall changes over the last 10 years. Some, consistent with regional records of rainfall, point to an increase in rainfall compared to the previous decade (Olsson *et al.* 2005; Ahmedou *et al.* 2009). Others, either due to a different point of comparison or to locally-specific experience, point to a rainfall decline. The sites to the north (Goudam, Gourma-Rharous, Gao, Ansongo) emphasize the reduction in the number of water points and the general insecurity associated with rebels and thieves as reducing their access to pasture and water. A more ubiquitous change is the increased prevalence of cropped fields at key pastoral sites such as water points and pastures (irrigated plots to the north, rain-fed and irrigated fields to the south).

A follow-up question asked of all informants was how the observed changes affected livestock movements. Only for the change of an increased number of fields do we have sufficient number of cases to merit in-depth analysis. For these,

interpretation is difficult since in a number of cases, this is not the sole change mentioned. Of those that mentioned how crop expansion has affected the distance to the ultimate pasture destination, 27 % stated that there was no change while 53 % and 20 % stated that there was a shortening and lengthening of distance respectively. These responses varied significantly by latitude with all those mentioning a shortening of the distance in the south and all those mentioning a lengthening of the distance in the north. Because of the difficulties of movements, the time away from the home base declined according to 75 % of those that mentioned the length of time away (25 % stated that there was no change). Of those mentioning it, the frequency of movements between encampment points was said to stay the same (37 %); increase (42 %) or decrease (21 %). This mixed characterization points to a trend, within areas of expanding cropped area, of reduced time spent at certain encampment points while dramatic increases in others as reflected in these three statements:

> Our animals spend less time at the same encampment point due to the low quality of forage [Increase]
>
> Certain encampment points are abandoned with herders spending a lot of time at other encampment points even multiple times during the year [Decrease]
>
> We pass less time at certain encampment points and very much more at others. [Decrease]
> (notes from interviews in Kollo)

Responses to the question of whether past conflicts at any location used by their livestock have caused them to avoid it provide further insights into changes in livestock movements that have occurred. Of the 49 responses that adequately addressed the question, 8 % stated that there was no conflict and 31 % stated that past conflicts have not influenced their movement decisions. Of the remainder, 67 % stated that past conflicts with agriculturalists influence their movement decisions; 63 % stated that past conflicts with government agents influence their movement decisions; and 17 % stated that past conflicts with other herders influence their movement decisions.

Livestock Movement Decisions

Informants were also asked to list the types of information important for making more routine decisions about the destinations of livestock movements. Once the group had identified these, they were asked to categorize each as either "absolutely necessary" or "simply helpful" in making such decisions. Table 9 lists the percentages of the most commonly mentioned information types that were subsequently categorized as absolutely necessary or simply helpful. During the rainy season, pasture quality, level of rainfall, density of vegetation, and presence of livestock diseases were mentioned in 70 % of the interviews with the majority of the first three information types seen as absolutely necessary. The presence/absence of livestock disease is mentioned more often for the dry season (73 %). It, along with pasture quality, spatial extent of pastures, and density of vegetation, are reported to be the most important in terms of absolutely necessary pieces of information for evaluating places as potential destinations during the dry season.

Table 9 The percentage of group interviews (n=64) in which respondents mentioned a particular type of information about a potential pasture destination as being absolutely necessary (Nec) or simply helpful (Hlp) during the rainy and dry seasons

Type of information about potential destinations	Rain season		Dry season	
	Nec	Hlp	Nec	Hlp
Pasture quality (species composition and greeness of vegetation)	77	8	61	5
Level of rainfall	52	27	–	–
Density of vegetation	61	14	45	9
Presence or absence of livestock disease	36	36	39	34
Spatial extent of pastures	48	20	41	27
Presence or absence of fields	25	39	19	34
Number of herds based at location	5	56	25	28
Presence or absence of troublesome wild animals	11	48	13	42
Presence or absence of thieves or government agents	5	47	5	53

As a follow-up to these responses, informants were asked about their sources of information about the state of pasture and water sources at potential destinations. Once they provided these sources, they were asked to rank them in order of preference. Five sources of information were most often mentioned: 1. the radio; 2. questioning people at weekly markets; 3. a trusted local informant; 4. the telephone; and 5. visiting the location oneself or sending someone there. The radio and the market were the lowest ranked sources of information (normalized rank scores of 0.26 and 0.31 respectively). Informants pointed to the overly general information provided by the radio and their limited confidence in information gathered at the market. We would expect that the telephone is likely to be used to call a trusted local informant. If we combine the telephone and trusted local informant together, the combined source category is still ranked significant lower than visiting the potential site oneself or by a representative (normalized rank scores of 0.52 and 0.87 respectively). Clearly, informants would most prefer to visit the site themselves (or by one of their kin) before sending livestock to the location.

Providing rainfall predictions to rural peoples is often seen as a useful development strategy to reduce their vulnerability to rainfall shortfall. All informants had experienced such predictions as broadcast on the radio. This past experience very much influenced their responses when they were asked

whether rainfall predictions for their area would be useful for their livestock husbandry. Some stated that such information would help them decide whether to buy feed supplements or to sell animals. The vast majority of groups stated that such information would be of little use since such information: 1. has often been wrong leading to improper decisions; 2. is not sufficiently detailed to provide information about their alternative destinations; 3. would never change their destinations since they: a. only move to a location if they know it has grass, b. have a broader range of criteria affecting where to go than simply rainfall; OR c. do not have a wide range of choices of where to move to. A number of paraphrased quotes of informants better illustrate these findings:

> We listen to the radio very often but we never change our decisions regarding the destinations where our animals graze, when they graze outside of the village's soil. What you forget is that we don't have the choice where to send the animals so regardless of what the radio tells us, our animals will go to the usual places.
> (notes from interviews in Mopti)

> We do not find this information useful for livestock husbandry. We do not choose our grazing sites by chance. We never discuss before God's work, in other words we wait for the rains before we decide.
> We never find this kind of information useful since we do not determine a destination with radio. We have criteria for going to particular distant pastures. It is necessary for us to see for ourselves the spatial extent of pastures, density of vegetation, number of crop fields, and the presence of animals [at possible destinations].
> (notes from interviews in Gossi)

> No, because this information from the radio is not very precise and we especially want information on the sites [encampment points] that we are accustomed to visit—it is these that interest us. We don't want ruptures between our first site and our last site, except for short distances, since we need continuity of pasture and water along our transhumance path. If there are problems at any of our usual sites, we will delay our departure or change our direction.
> (notes from interviews in Kollo)

Discussion

The findings of our surveys support the conclusion that livestock husbandry represents an important component of the livelihood strategies of rural households—no matter their socioprofessional identity. Therefore, while "herding" and "farming" identities persist and help frame social conflicts in the area (Moritz 2006; Turner *et al.* 2011), they are best seen not as exclusive categories. All ethnic/caste groups are involved in farming and livestock husbandry. Contrary to common understandings that livestock husbandry becomes more dominant as annual rainfall declines, we do not observe such a relationship across the latitudinal range of this study (12.5° N to 16.5° N). Villages where we see the lowest rates of livestock ownership among farmers are actually found in the north (Gao, Goundam, Ansongo).

Livestock owners, no matter their socioprofessional identity, value extra-village mobility in the management of their livestock. This finding is supported not only by informants' statements in group interviews but by the limited effect of socioprofessional composition on observed patterns of livestock mobility. Interviews do show that one's proclivity to be engaged on a day-to-day livestock management away from the village is affected by socioprofessional identity with those having "herding" identities continuing to dominate the day-to-day grazing of those livestock that leave the village territory (Moritz 2006). Owners without herding identities typically hire or entrust their livestock to those with herding identities to herd outside of the village territory since the later hold the necessary knowledge and social contacts to do so. Our informants state that when trust declines between livestock owners and herders, livestock are more likely to remain in or within 40 km of the village territory.

Our respondents stated that the advantages of extra-village movements outweigh the disadvantages, particularly during the rainy season (Tables 7 and 8). Moving livestock outside of the territory during the rainy season results in access to better pasture; access to larger pasture areas; and facilitates responses to changing forage conditions. Clearly, such movements are seen as benefitting the nutrition and health of livestock. On broader socioeconomic issues, the benefits are less clear. An economic disadvantage of extra-village herd movements is that it takes livestock away from the village when their owners may want to sell them or sell or use their products (milk, traction). While respondents point to the advantages of avoiding local crop damage, they also point to the vulnerability of herds to crop damage fines when outside of the village territory. As discussed above, this reflects a scale issue—advantages of livestock movement as it relates to cropping turn to disadvantages when livestock must move through areas of high cropping pressure to access pastures outside of the village territory.

During the dry season the advantages and disadvantages are more evenly weighted with all centered on the risks and benefits to animal health and nutrition. As a result, we observe less extra-village livestock movements during this season (Table 4). The most significant advantages to extra-village territory movements are to provide livestock with better access to forage and water. The disadvantages, on the other hand, are the additional energy expenditures for livestock of

moving them elsewhere and the risks of moving outside of the village territory but failing to find adequate forage and water. A major issue is the degree to which herd managers have access to quality information about the state of pastures and water at potential destinations (Table 9). Livestock managers show strong preference to visit a place themselves or by their delegate before sending their livestock there. Scouting for possible sites, takes significant time and effort but is much more sure (compared to gathering information at the market) and relevant to their specific needs (radio on other government-sponsored information sources). Calling a friend or family member who is near or recently visited the site is seen as a viable alternative but is still less favored than seeing the place oneself. This is not because of lack of trust but because of the difficulty in gathering all necessary information from even a trusted informant.

The prevalence of extra-village movements is greater in densely-populated areas (Tables 5 and 6). This is consistent with previous studies showing greater movements out of highly-cultivated areas to gain access to necessary pasture (Lhoste 1987; Bonfiglioli 1990; de Haan *et al.* 1990; Lericollais and Faye 1994; Turner and Hiernaux 2008). However, it counters common interpretations of population-induced intensification (Boserup 1965) in the region that increased land scarcity will stimulate greater integration of livestock husbandry with crop agriculture with a necessary decline in livestock mobility (Bourn and Wint 1994; Powell *et al.* 1995). Given the importance of livestock husbandry for all rural peoples in the region, local pasture scarcity will lead to increase extra-village movements of livestock unless there is sufficient income generated to purchase livestock feed (e.g. Lericollais and Faye 1994; Moritz 2012).

Livestock husbandry represents an important part of the livelihood strategies of all rural peoples of the region. According to our informants, the advantages of livestock mobility are seen to outweigh its disadvantages—particularly during the rainy season. These views are consistent with the existing scientific literature (Sandford 1982; Wilson 1989; Scoones 1994; Fafchamps and Gavian 1996; Niamir-Fuller 1999; Pedersen and Benjaminsen 2008). Still, we observe a range of livestock mobility patterns across the 32 study villages inadequately explained by the broad-scale regression analysis. This reflects the differential opportunities and constraints facing livestock owners and managers working at the local level. Based on the findings of our interviews, three types of situations most likely lead to lower mobility categories (Fig. 2) in either the crop season (1,2,3) or dry season (1, 4, 7).

1. Villages composed largely of farmers who lack sufficient trust in herders to send their livestock with them away from the village. While we did not pose questions directly about trust, unsolicited statements by our informants point to some problems between livestock owners and herders. Districts where this issue may have contributed to lower mobility of village livestock as a whole include: Madarounfa, Mirriah, Gao, Kollo, and Koro.
2. Villages within districts where herd movements outside of the village territory are constrained by high cultivation pressure. While mobility was found to increase in areas of higher population density, informants report that cultivation inhibits livestock movements. Inhibition is associated with increased farmer-herder conflict, a reduction in the number of livestock corridors, the abandonment of certain encampment points, and longer stays at other encampment points. Pasture shortage stimulates movements out of an area but inhibition of these movements is not typically caused by a lack of space for corridors and encampment points but by failures in local land-use protections and governance that allow chaotic incursions of cropped fields onto corridors and near encampment and water points.
3. Villages located in areas of pasture which serve as points of destination during the crop or dry seasons. This possibly explains the lower than expected mobility during the crop season of livestock in Ansongo and Gourma-Rharous—two districts with majority herder populations within sampled villages (Table 3). These are areas that have historically served as important pasture destinations (for local as well as herds based to the south) during the crop season (de Bruijn and van Djik 1995).

Conclusions

This research provides quantitative and qualitative evidence for the importance of livestock and the mobility of livestock for the resiliency of rural livelihoods in semi-arid West Africa. Rather than historic relics of the past, movements of livestock across open rangeland conditions continue to be necessary as populations increase and dryland climates become more variable. The resources needed for mobility include: herding labor, trust among livestock owners and managers, space for passage from home to seasonal destination, information about risks and rewards tied to different locations, destination pastures of sufficient extent and quality, and high quality water sources along the route. Many of these resources are commonly-held. This is clear when it comes to common pastures and water sources but even herding labor and information is shared. Labor is shared when livestock are entrusted to herders, herders are hired, and people combine their livestock into commonly-managed herds. Information is shared between herders of the same clan, people at the marketplace, or on the radio. Therefore the management of these resources necessarily depends on effective social institutions which require careful attention to maintaining the

quality of these resources and the forms through which access to them is gained.

Given their inter-connected nature, livestock corridors, waterpoints and encampment sites—resources necessary for movements of livestock from one point to the next—need to be protected from competing land uses. Erosion of these landscape features do not reduce the need for livestock to move and will lead to a combination of increased farmer-herder conflict and reduced mobility with costs to livestock productivity, household economies, and social cohesion. Likewise, institutions that facilitate labor sharing and build trust among livestock managers and owners will help maintain or increase livestock mobility. Improvements in the dissemination of information about pasture conditions are also needed. As shown by the responses of our informants, radio-disseminated information is inadequate and information provided through social networks is questioned. As a result, most herders rely on scouting with significant labor costs to their households. Improvements can only be developed through careful attention to the political economy of information. If information is too widespread, its usefulness declines. In many cases, the provision of information about specific pastures to the social networks (kinship ties, territorial groups..etc.) that rely on them may be more effective than widespread dissemination of pasture information (radio). More attention needs to be directed at these and other initiatives to support the livelihoods of all rural peoples in semi-arid Africa.

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