JANUARY 2019

Transforming Pastoralist Mobility in West Darfur: Understanding Continuity and Change

A FEINSTEIN INTERNATIONAL CENTER PUBLICATION

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Citation: Sulieman, H. and Young, H. *Transforming Pastoralist Mobility in West Darfur: Understanding Continuity and Change*. Boston: Feinstein International Center, Tufts University, 2019

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This material has been funded by UK aid from the UK government; however the views expressed do not necessarily reflect the UK government's official policies.

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Acknowledgements

This work was made possible through the support of a large number of people beyond the Building Resilience in Chad and Sudan (BRICS) partners, including staff from the federal- and state-level Ministry of Animal Resources. Special thanks are due to Dr. Ammar El Shikh Idris Omer, Director General of Livestock Economics and Planning Directorate, Ministry of Animal Resources. Thanks are also due to the Ministry of Animal Resources for their excellent support and facilitation, including of the devices.

We would especially like to acknowledge and thank the following people, without whom this work would not have been possible.

From El Geneina and Kulbus Locality:

- Dr. Mohamed Elamain Deri, State Focal Point for this study and Director General of the Ministry of Livestock;
- Dr. Rabie Salih Adam, Focal Point for this study for El Geneina Locality;
- Dr. Ahmed Mohamed Fadul, Focal Point for this study for Kulbus Locality;
- Dr. Nadia Ibrahim Ahmed, Director General, Ministry of Agriculture and Natural Resources.

From the tribal leadership, we would like to thank and acknowledge the following individuals who gave their support throughout:

- From Telehaya: Omda Abaker Sakha, Omda Ahmed Hassan, and Adam Mohamed Benda;
- From Kulbus: Zakariya Yahya Bushara, Sulieman Abdelrahman, and Mustafa Ibrahim Ahmed.

We would like to thank the staff of Concern Worldwide (CWW) in Kulbus, Geneina, Khartoum, and London for help with planning, administration, logistics, and coordination, especially Friday Mwaba, Gretta Fitzgerald, Michelle Wilson, and Barbara White.

We are extremely grateful to Madeline Wrabble for the mapping and extraction of the precipitation data. For copy editing, we thank Liz Vincent. For design and formatting, we thank Jess Haswell.

For project management, coordination, and unerring support to every step of this process from start to finish, we gratefully acknowledge and thank both Anne Radday and Abdelhafiz Mohammed.

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Summary

In the Darfur Region of Sudan, patterns of livestock mobility and livelihood systems are continually adapting and transforming themselves in the face of multiple challenges. Earlier studies have shown that pastoralist mobility offers significant production advantages and enables pastoralist herds to access the best-quality grazing during the rainy season as they selectively target the new, more nutritious growth. Mobility also allows pastoralists to minimize time spent in difficult conditions (mud, flies, and overcrowding or overgrazing), while also maintaining dry season pasture and fodder reserves. Some of the challenges to livestock production are well known and documented. However, little is known about how livestock keepers cope with and manage extreme climate variability, and potential insecurity and conflict, and how this coping differs according to systems of livestock production and mobility patterns. In 2017, we undertook a study to improve our knowledge of these factors in West Darfur, Sudan.

Using Global Positioning System (GPS) tracking devices, we tracked livestock herds (sheep, cattle, and camel) of 13 livestock keepers for six months, from April to September 2017. The herds came from two areas in West Darfur: El Geneina Locality (Telehaya) and Kulbus Locality (Goshosh and Bir Taweel).

We used the GPS data to produce maps illustrating the movements of each herd during part of the hot dry season (*seif*), the rainy season (*kharif*), and the pre-harvest and harvest period (*deret*). These are the seasons when interaction between herders and farmers are most active. The maps allow a comparative analysis by season, by livestock species, and by pattern of mobility (distant, close, or sedentary).

The annual cycle of mobility differs according to whether livestock keepers are specialists in farming (Goshosh and Bir Taweel communities) or in pastoralism (Telehaya community). The traditional livestock corridors (*murhal*) linking the rainy season grazing areas in the far north on the edge of the Sahara with the dry season grazing areas in the south extend from 500 to 600 kilometers (km). At the other end of the spectrum is the more localized mobility of small herds owned by farmers in the vicinity of their villages.

Patterns of mobility have changed. We identify three territories of movement, or grazing zones: **home area** (1–5 km); **close grazing land** (6–19 km); and **distant grazing land** (20–100 km). Compared to the past, these territories are retracting closer to the home area.

The livestock keepers who practice **long-distance mobility** divide their cycle of movement between the three zones. They spend *seif, rushash* (season in which the rains begin), and *kharif* in the distant grazing land away from their home area. Towards the time of harvest, they proceed to their home area to benefit from the *talaig* (the practice of common access of livestock to graze crop residues after the harvest has been taken in), where they stay for the whole of *shita* (cool dry season), grazing on crop residues and pastures around the village. **Short-distance mobility** is concentrated in the close grazing zone and is the most popular zone in both communities, with herds spending about 45% of their annual cycle of movement in this zone. As a result, livestock keepers report that pasture is rapidly deteriorating due to the high concentration of livestock. In the **sedentary system of mobility**, livestock grazing is confined to the home area all year round. This sedentary system is practiced by settled communities, primarily farmers; however, pastoralists also do this when facing periods of conflict or threat of looting.

All livestock keepers in this study identified insecurity as their predominant concern. The restricted patterns of mobility described above are a preventive response strategy to counter security risks. Livestock keepers avoid remote pastureland that might put them at risk from bandits and armed groups. Additionally, the lack of water for livestock in

the distant northern part of the migration is pushing livestock keepers to reduce the time spent there despite the availability of quality pasture. As a result, livestock keepers must make trade-offs between the threat of insecurity and looting versus the risks of overgrazing, poor-quality pasture, overcrowding, and disease. Thus, livestock keepers design and manage the annual cycle of movement to sustain and protect their herds and support household food security and other livelihood goals.

Dry years (*mahal*) and floods are characteristic of this region, some more severe than others. For example, Telehaya livestock keepers described the effects of the 2017 *mahal* as particularly bad because of the competition from camel herds from Chad for limited water and fodder resources. Significant livestock deaths were reported. Drought coping strategies include higher frequency movement, tree cutting to use seeds and pods as fodder, use of feed concentrates, and destocking. These strategies risk overgrazing and degradation of tree cover. Flash floods during the early rains are also dangerous, as livestock are concentrated around the *wadi* (valley that has a seasonal water course). There is little pastoralists can do to avoid this danger. Conflict responses include: keeping small livestock herds within the village; moving larger, more mobile herds in bigger groups to support each other; using guard dogs to watch livestock at nighttime; looking for alternative, but longer, routes when corridors are blocked; and reducing the pattern of distant mobility. None of these responses adequately address the problems faced, and so there is a need for a more collaborative and considered institutional, policy, and programmatic response involving discussing the issues with both the local- and state-level authorities and other stakeholders. The report presents provisional recommendations to serve as the basis for further discussion.

1. Introduction

In the Darfur Region of Sudan, patterns of livestock mobility and livelihood systems are continually adapting and transforming themselves in the face of multiple challenges. While some of the challenges to livestock production are well known and documented, little is known about how livestock keepers cope with and manage extreme climate variability, potential insecurity, and conflict, and how this differs according to systems of livestock production and mobility patterns. An understanding of these processes is directly relevant to policies, programs, and other actions that support and build the resilience of these core livelihood systems by strengthening people's capacities and reducing their vulnerability. Lessons learned in the Darfur context are likely to be groundbreaking given the scale, intensity, and protracted nature of climate extremes and disasters in Darfur Region, and will have considerable relevance to resilience building across the Sahel and to dryland regions globally.

In this report we compare the livelihoods, herd management practices, and seasonal patterns of mobility of 13 individual livestock keepers and their livestock herds from West Darfur.[1] We then analyze the rationale and role of mobility and subsequent resilience of livestock production systems and local livelihoods to climate- and conflict-related stresses and shocks. The study is a part of a mixed methods longitudinal study in the Darfur Region of Sudan on livelihoods, nutrition, and resilience, which took place between 2016 and 2017 as part of the Building Resilience In Chad and Sudan (BRICS) program, led by Concern Worldwide (CWW) with partners Feinstein International Center, Friedman School of Nutrition Science and Policy at Tufts University, Al Massar, and the World Agroforestry Centre (ICRAF) from 2015 to 2018.[2]

The study aims to investigate community livelihood resilience to climate extremes in a conflict-affected drylands setting, with a view to informing and influencing the BRICS partners, wider national and local stakeholders, and the wider Building Resilience and Adaptation to Climate Extremes and Disasters (BRACED) global initiative.

The livestock keepers in this study are drawn from two different locales representing broadly two different livestock traditions: one group of recently settled nomadic livestock keepers practicing pastoralist production in Telehaya, near El Geneina, West Darfur; and one group of more traditional farmers, who are raising livestock as part of a more mixed farming system in communities near Kulbus, West Darfur.

The study is rooted in the earlier scholarly work on Darfur and pastoralism in Sudan and the region, and also on more theoretical considerations and understanding of pastoralism and socio-ecological resilience, which are briefly presented in the rest of the introduction, along with a description of the study area and its climatic patterns, especially focusing on precipitation.

1 Note on terminology: the report refers to livestock keepers, who are in this case both the herd owner and the herd manager. The livestock keepers in this study have different livelihood traditions and identities. In the past, the Telehaya community was nomadic, and members still identify themselves as nomads, although many have settled their families in Telehaya and now farm, although pastoralism (moving with their herds) remains their core livelihood activity. The Kulbus communities have a long tradition of sedentary farming, complemented by livestock production. Hence the term "nomad" is used here to refer to identity, while "pastoralism" refers to a mobile system of livestock production.

2 There are two related papers based on this longitudinal study, one on the resilience of livelihood systems in Darfur (entitled: Complexity, continuity and change: Livelihood resilience in the Darfur Region of Sudan) and a second on the seasonality of acute malnutrition and its drivers.

Section two presents the methods, outlining stakeholder engagement at all levels, selection of communities and livestock keepers, and research methods and tools. In Section three, we review the livelihoods of the selected livestock keepers, including the complementarity and diversification of livelihood activities, their livestock ownership, and strategies to improve efficiency and cost effectiveness, as well as integration with farming. The roles and responsibilities of household members are also reviewed. Section four provides an overview of the annual cycle of movements in response to seasonal changes. It also describes daily routines and management practices. Section five presents an in-depth spatial and temporal analysis of livestock mobility, based on the GPS tracking of livestock herds over six months. This analysis contrasts the more sedentary livestock keepers from Goshosh and Bir Taweel, Kulbus Locality with the settled pastoralists and former nomads from Telehaya (El Geneina Locality). Section six reviews the livestock keepers' coping and adaptation strategies in response to the risks of insecurity and conflict and climate extremes.

1.1 Background: Resilience from a socio-ecological perspective and the non-equilibrium paradigm for drylands development

An understanding of the resilience of livestock production and pastoralist mobility needs to consider both the environmental drivers of mobility linked to climate and ecology, as well as the social and economic influences on herd management and herder decision-making. This means that our interest in resilience is with both the social resilience of communities, linked with their capacities, and with the resilience of the wider ecological system and how that functions (Adger 2000, Folke 2006, Bousquet, Botta et al. 2016). This ecological perspective pioneered by Hollings (1973) seeks to open up a management approach capable of sustaining productivity under conditions of extreme instability (Walker and Cooper 2011). As argued by Perring, Folke et al., "Social-ecological systems act as strongly coupled, complex and evolving integrated systems" (p. 437). In other words, these factors should not be considered or treated independently (Perring, Folke et al. 2002). These arguments supported the development of a new paradigm on drylands development, which might be summed up as a system that recognizes that drylands do not have a single state of equilibrium and instead are characterized by extreme variability, especially precipitation, and are thus more accurately described as a non-equilibrium environment (Behnke, Scoones et al. 1993, Scoones 1995). In such contexts, producers (farmers and pastoralists) are managing variability as their strategy to optimize production (Mortimore 2009), in contrast to earlier, now-discredited development notions of optimizing "carrying capacity" in drylands.[3] Hence, our concern is not only how livestock producers manage the extreme climate variability and ecological diversity that is characteristic of Darfur, but also how they balance the coinciding social and economic pressures on their livelihoods.

1.2 Background: From a symbiotic relationship to competition and conflict

The two traditional systems of agricultural production in Darfur Region correspond to the two main livelihood sub-systems: farming and pastoralism. Traditionally, the relations between the two sub-systems, often described as nomad-sedentary relations, were highly integrated and together formed a wider livelihood production system that covered the entire region (Barth 1973, Abdul-Jalil 2008). In the past, a symbiotic relationship existed between farming and pastoralism, with the two production systems enjoying mutual benefits as a result of their integration (Osman, Young et al. 2013). Changing land use practices, including the expansion and intensification of agriculture and erosion of some customary institutions, have brought pastoralists into conflict with farmers (Glover 2005, Manger 2005, Abdul-Jalil 2008, Sulieman 2015).

At the same time, it is evident from the BRICS longitudinal study and others (Young, Osman et al.

3 Carrying capacity is the maximum population of livestock that an area will support without undergoing deterioration.

2005, Abdul-Jalil 2008) that increasingly farmers are raising livestock, while pastoralist households are also now cultivating crops. This suggests a high level of/or increasing diversification at the level of the household, with a simultaneous loss of the livelihood specialization and integration that once characterized the regional livelihood system. Abdul-Jalil (2008) argues the trend of sedentary cultivators increasingly investing more in livestock breeding for commercial purposes is driven by the increase in Sudan's export of livestock (mainly sheep), and that farmers are consequently in competition and potentially conflict with pastoralists This merging will have implications for resilience and sustainability that are further explored in this study.

Other studies have shown that the mobility of livestock and pastoralist migrations in Darfur Region have changed significantly in the past two decades in response to climate and conflict shocks, and economic and environmental trends (Young, Osman et al. 2009, Young, Sulieman et al. 2013, Krätli, Eldirani et al. 2013, Young, Behnke et al. 2016). More broadly in Sudan and in Darfur Region, there are reports of shrinking rangelands (UNEP 2007) as a result of increasing farmland (including traditional rainfed and mechanized farming), fencing of pastures,[4] farms blocking the livestock corridors that link seasonal grazing areas, and a decline in traditional institutions, such as the post-harvest sharing of crop residues by the entire community (Fadul 2004, Abdul-Jalil 2008). Mobility is further hindered as a result of conflict, insecurity, and the threat of looting (Young, Osman et al. 2005, Young, Osman et al. 2009, Young, Sulieman et al. 2013, Young, Behnke et al. 2016).

1.3 The study area

West Darfur is located in the westernmost corner of Sudan along the border with Chad (see Figure 1). Harrison and Jackson (1958) classified this part of the country (West Darfur State) as low rainfall woodland savannah. This woodland savannah is composed of a mix of grasses with bushes and trees (Harrison and Jackson 1958). A significant proportion of this natural vegetation has been destroyed in the course of widespread anthropogenic factors in densely populated areas such as crop cultivation, extensive burning, and wood collection (UNEP 2007, UNEP 2008). However, more remote and insecure areas that were depopulated during various periods of conflict still maintain healthy vegetation cover. Examples of such areas are Jebel Moon and the northern parts of Wadi Aradeib on the border with North Darfur State (see Figure 1).

1.4 Rainfall variability and its implications for livestock movement

The rainfall in West Darfur is monsoonal, with a single rainy season (see Table 1). There is a clear rainfall gradient, with annual rainfall decreasing from south to north. The average annual rainfall isohyets for the period from 1998 to 2017 ranged from 660 millimeters (mm) to less than 300 mm. The spatial variation in rainfall is the main factor in vegetation growth and land use.

The rainy season starts earlier in the south than in northern parts due to the south–north rainfall movement of the inter-tropical zone of convergence. Light showers begin around mid-May, and heavy rainfall typically occurs in July and August. The rainy season ends towards the end of October. Being part of the African Sahel, there is significant inter-annual variability in rainfall totals. This variability can be observed at temporal and spatial scales as illustrated in Figure 2 of Kulbus and Figure 3 of Telehaya. Most of the annual rainfall in Telehaya (74%) and Kulbus (79%) is concentrated in July and August as shown in Figure 4 (a, b).

Rainfall is a critical climatic element for pastoralism and farming. Below a certain threshold of annual rainfall,[5] both activities are primarily controlled by water availability, which is typically limited to a relatively short season and erratically distributed rain in time and space within a region that is particularly sensitive to small changes in rainfall.

4 "Air fences" (*zareibat al hawa*), which are fenced areas within the pasture lands, severely damaged the relationship between nomads and settled farmers (Fadul 2004).

5 "In the Sahel, the transition from growth determined mainly by nutrients to that determined by water occurs at an annual rainfall of about 300 mm. Water is thus the limiting factor for plant growth only in the northern half of the region" (Bremen and de Wit 1983, 1342).

Figure 1. Map of West Darfur.

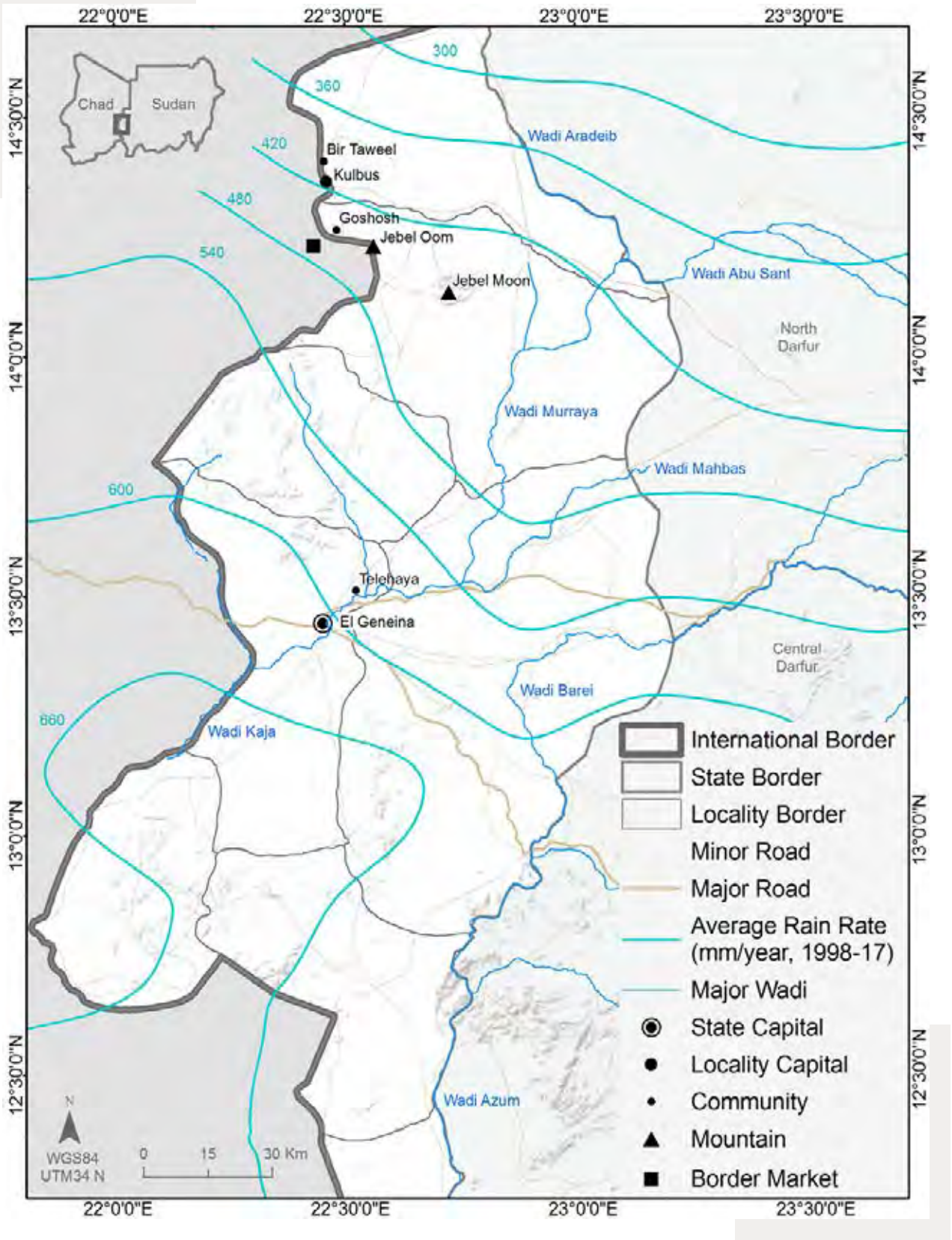


Table 1. Duration and short description of the seasons of the year.

	Season	Approximate duration	Short description
Rainy season	*Rushash*	Mid-May to Mid-June	Start of intermittent light rain showers Temperatures decrease Grasses start to grow
	Kharif	Mid-June to end October	Heavier, more established rains Higher humidity, cold breezes, and lower temperatures Surface drinking water available
	Deret	October to November	End of rains Increase in temperature Maturation and harvesting of crops
Dry season (cool)	*Shita*	November to February	Cool dry season
Dry season (hot)	*Seif*	March to Mid-May	Hot, sometimes windy and dusty Limited pasture Lack of water for people and livestock

Notes: Communities view the first rains in *rushash* as the start of the climatic year; Our livestock tracking started in *seif* and continued up to *deret*.

Figure 2. Rainfall patterns in Kulbus show strong seasonal difference in inter-annual variability of rainfall totals based on Tropical Rainfall Monitoring Mission (TRMM) 3B43 Satellite Precipitation Estimates (SPE) for the period 1998–2017.

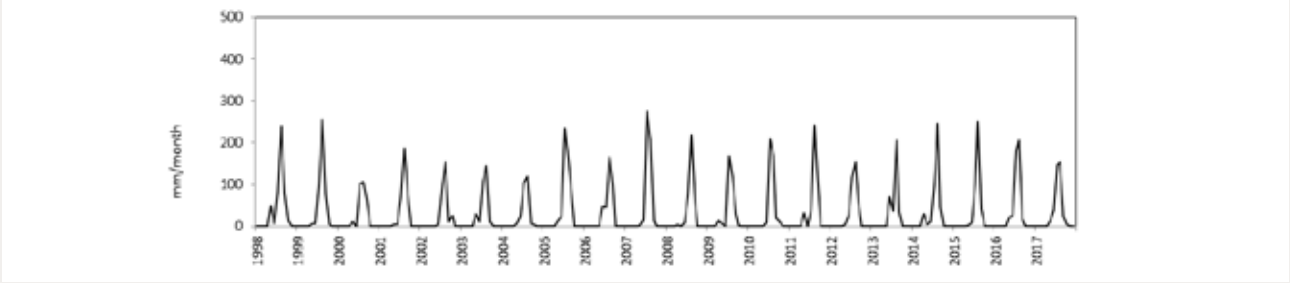


Figure 3. Rainfall patterns in Telehaya show strong seasonal and inter-annual difference in rainfall totals based on TRMM 3B43 SPE for the period 1998–2017.

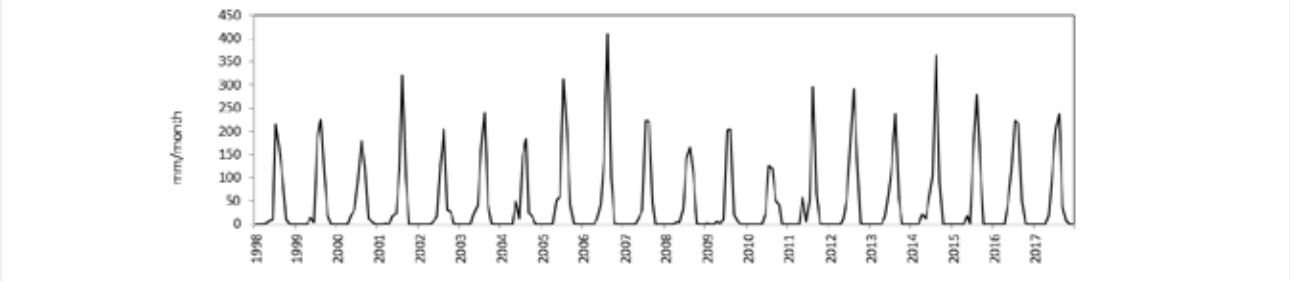
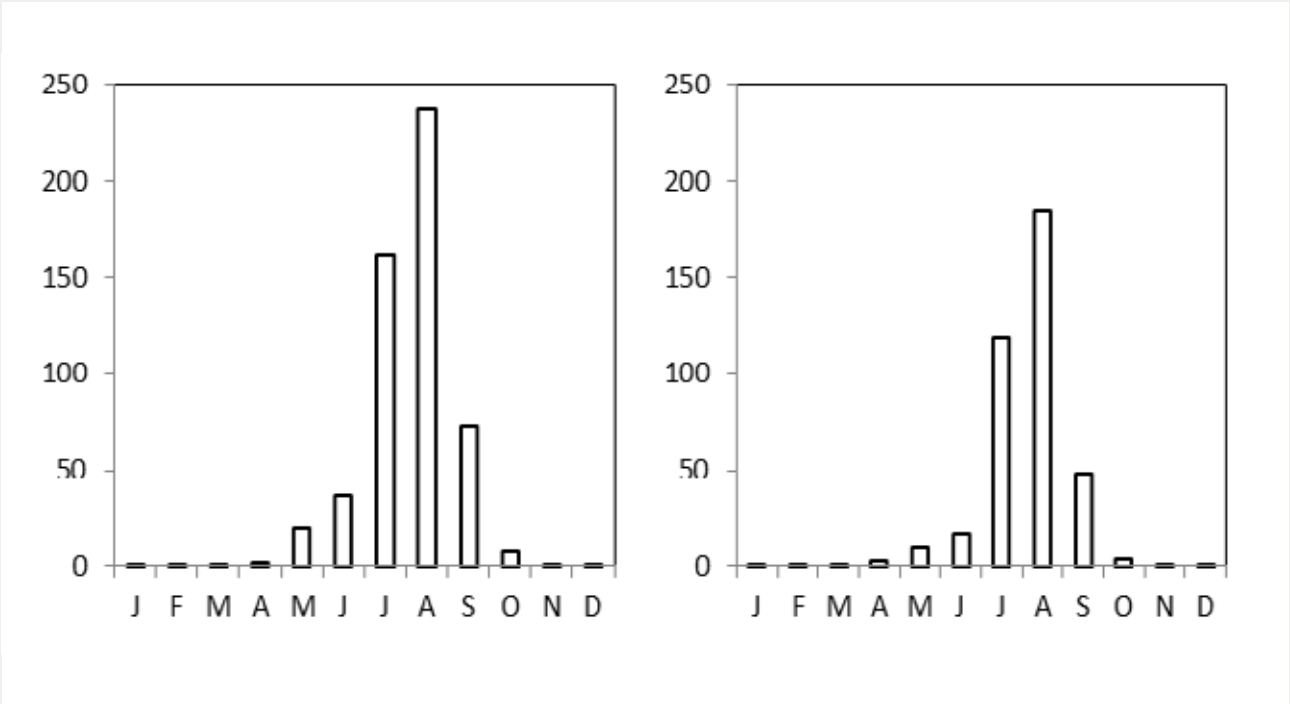


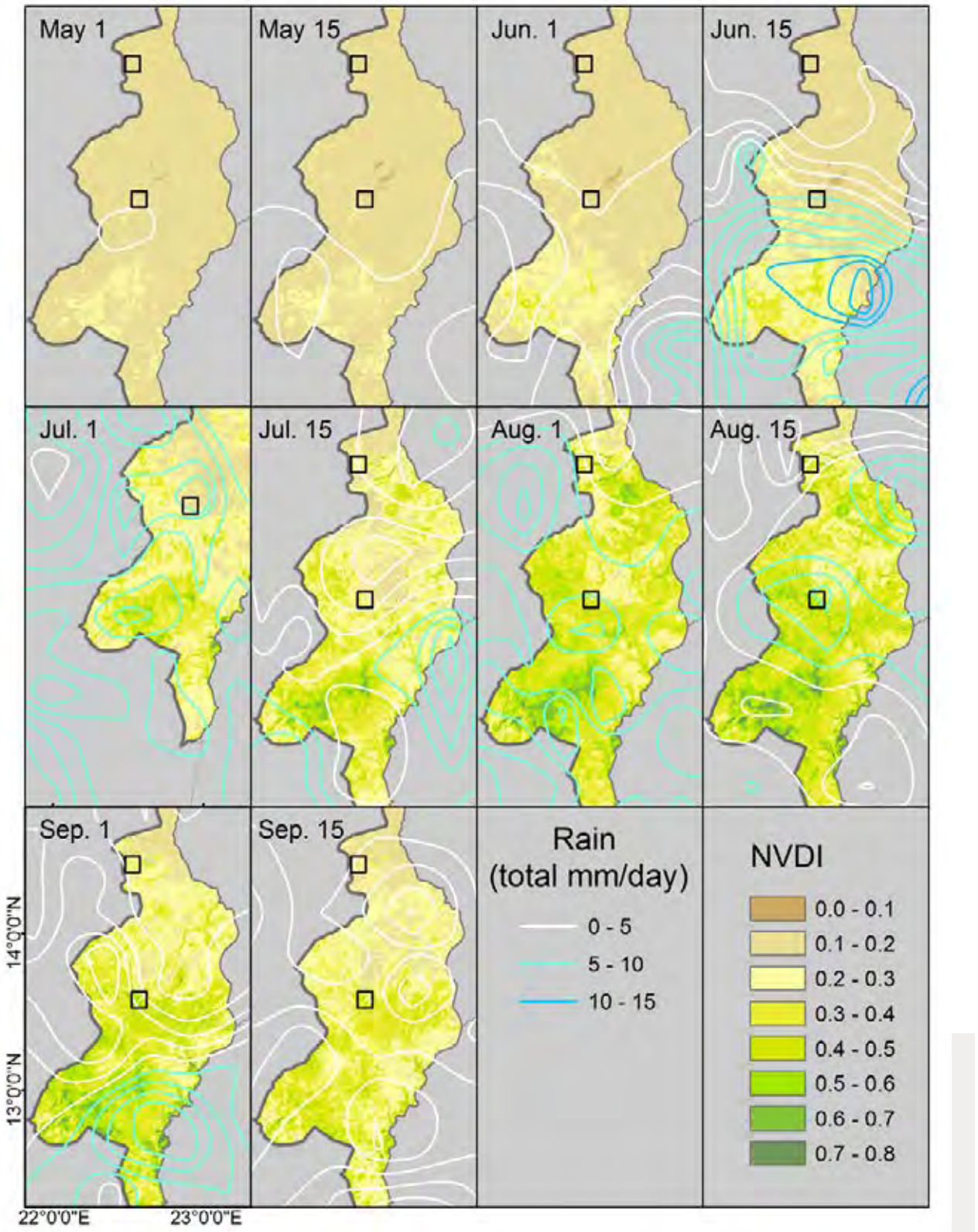
Figure 4. Mean monthly rainfall (mm) for (a) Telehaya and (b) Kulbus for the period 1998–2017.



The rainfall gradient and rainfall variability influence the quantity of biomass produced and its nutritional quality. As rainfall increases in the south, growth of biomass increases, as reflected in the higher levels of Normalized Difference Vegetation Index (NDVI), but conversely the protein content decreases (Bremen and de Wit 1983). Farther north where annual rainfall is less than 300 mm per annum, water availability determines growth, not nutrient availability, and the protein content is significantly higher (12% as compared to 3%), although biomass is less (Bremen and de Wit 1983).

Figure 5 is a series of maps illustrating the biweekly rainfall and vegetation (NDVI) patterns over the study period from May 1 to September 15, 2017. These maps clearly illustrate the gradual greening-up spreading north and then beginning to ebb towards the end of the rainy season.

Figure 5. Seasonal vegetative growth and rainfall from May 1 to September 15, 2017.



2. Methods

2.1 Approach

This study deals with the ways communities manage their livelihoods to enable them to address the challenges they face in the path to recovery after crisis—to return to self-sufficiency and achieve sustainable livelihoods for the future. The study takes an interdisciplinary mixed methods approach. The methodology builds on experience from a series of previous studies on pastoralism in Sudan conducted by the Feinstein International Center, Friedman School of Nutrition Science and Policy at Tufts University (Tufts/FIC) and partners (Krätli, Eldirani et al. 2013, Young, Sulieman et al. 2013, Young, Behnke et al. 2016).

2.2 Engagement with stakeholders

This research was designed from the start to meaningfully engage with national- and state-level stakeholders to understand and reflect their interests as the research proceeded. The goal was to build a foundation of stakeholder support for this work nationally and at state, locality, and community level before the research started. The goal was also to learn about stakeholder interests and concerns, and to promote research uptake. The collaborative process also benefited the study, because the stakeholders brought diversity and depth of knowledge and experience to assist in the study. Furthermore, it allowed an opportunity to build capacities and develop skills, recognizing that different partners brought unique skills and also had specific skills gaps they were interested in addressing.

Stakeholder engagement started with a series of meetings and disseminations with national, state-level, and local stakeholders identified by Al Massar and CWW, and through community visits. The objectives of these meetings were:

- To inform stakeholders about the earlier work on pastoralist mobility in Darfur Region and its benefits;
- To explain how the proposed research activities fit with wider BRICS program goals;
- To get their views on the uses and benefits of the research;
- To understand and anticipate potential drawbacks and risks.

A "kick-off" workshop was attended by 16 organizations in El Geneina, West Darfur. Participants generally agreed that the study would create a better understanding of the traditional livestock rearing systems in the area and how they are changing. Participants also emphasized the need for good preparation and awareness-raising with local communities before introducing the new technology: the GPS devices.

The State Governor (*Wali*) and the Director General of the State Ministry of Agriculture and Natural Resources gave their full support and nominated two senior government focal points to collaborate with the BRICS team (one from the Ministry of Livestock and one from Ministry of Agriculture). At the federal level, the Ministry of Animal Resources directly supported this study by playing a facilitating role with the West Darfur State Ministry of Livestock. The State Ministry was actively involved in the research, including participating as part of the research teams. This stakeholder engagement demonstrated the strong demand for this type of research and illustrated the issues and interests of stakeholders (see Box 1) and their willingness to support the work in new ways.

2.3 Selection of communities and livestock keepers

The study aimed to include diverse livestock production systems, reflecting different species (camels, cattle, and sheep), methods of herding (individual or as mixed herds), herd sizes, and mobility patterns. These criteria made purposive sampling impossible, so we selected communities from the two localities to reflect different ecologies and rainfall patterns (Kulbus Locality experiences far

less annual rainfall than does El Geneina Locality) and meet the criteria.

Through consultation with the research partners, we organized introductory visits to identify potential communities in both areas. We chose one community in El Geneina Locality, Telehaya, and two communities in Kulbus Locality, Bir Taweel and Goshosh.

We then consulted with local leaders from each community to identify, select, and recruit livestock

Box 1. Issues and interests raised by national and local stakeholders at the beginning of the study.

- The important role of the study in supporting traditional pastoralist systems and local livelihoods, and the contribution they make to Sudan's economy
- Several known challenges facing traditional pastoralist systems and their mobility
- The need to better understand how land use and availability is changing and the associated availability and access to services and resources, such as water
- The issue of cross-border mobility to Chad and the Central African Republic
- The effects of climate extremes, climate change, and conflict on pastoralism, including the shift towards nomads settling
- Technical issues about the devices and how they work
- The significant role that traditional leaders can play at community level in terms of supporting the study team to introduce the new technology

Table 2. Summary of livestock species collared in West Darfur State.

No.	Locality	Community	Livestock keeper code	Livestock species		
				Sheep	*Cattle*	*Camel*
1	El Geneina	Telehaya	GT1	X	X	
2			GT2			X
3			GT3	X	X	X
4			GT4		X	
5			GT5	X		
6	Kulbus	Bir Taweel	KB1	X		
7			KB2		X	
8			KB3	X	X	
9			KB4	X		
10		Goshosh	KG1	X	X	
11			KG2		X	
12			KG3	X		
13			KG4		X	
		Total	**13**	**8**	**8**	**2**

Note on codes:
- First letter is the locality (G: El Geneina and K: Kulbus);
- Second letter is community (T: Telehaya; B: Bir Taweel; and G: Goshosh);
- Numeral is the livestock keeper number.

keepers to join the study. We selected 13 livestock keepers: five from Telehaya and eight from Kulbus (Goshosh and Bir Taweel). See Table 2 for details.

2.4 Research methods and tools

The study combined two methods: standard social research tools and geo-spatial technology for tracking livestock. The social research tools included semi-structured interviews, participant observation, and weekly telephone interviews. The geo-spatial technology used in this study includes GPS tracking devices fitted on animals and Geographical Information System (GIS), satellite-based vegetation index and rainfall estimates.

2.4.1 Social research methods

The lead researcher conducted detailed face-to-face, semi-structured interviews three times with each pastoralist: during the "collaring" visit,[6] the mid-term outreach visit, and the final visit to remove the GPS tracking devices. The interviews discussed personal background, livestock ownership, the annual cycle of movement, herd management, daily routine, livelihood activities, crises, and climate extremes (see Annex 1 for the interview guide).

We also conducted weekly phone calls with each herder in which a short interview captured the dynamic situation of livestock keepers during their movements. These calls also helped us maintain contact and momentum with the livestock keepers. The weekly questions were about emergence of livestock diseases, rainfall events, water sources, and fodder for herds.

Focal points in each locality, who were aware of the local context and trusted by the local community, carried out these calls. The information from the calls fed into monthly reports compiled by the West Darfur State focal point. In addition to the information from the herds, these reports provided an overview and update on the livestock sector in West Darfur in general, such as livestock distribution across the state, emergence of diseases, vaccination campaigns, new legislation and regulations (e.g., timing of *talaig*), cross-border issues, etc. The researchers conducted additional ad hoc unstructured interviews with key informants during the field visits; for example, with other knowledgeable pastoralists or local leaders.

2.4.2 Geo-spatial technology

GPS tracking devices

The GPS device we used was the Gipsy-5, developed by TechnoSmart (www.technosmart.eu). The devices recorded the following data: position (longitude, latitude, and altitude), speed, date, and time. TechnoSmart modified the device to enable it to store data onboard (archival), which could then be later downloaded to a computer using USB cables. We used non-rechargeable batteries, because they offer the longest life and are considered more reliable in the extreme heat but must be replaced when discharged. Prior to tagging the animals, we programmed the device to take one fix or reading every 30 minutes, 24 hours per day. Once programmed, we had leather cases and collars made out of local leather to use to attach the collars to the animals. To keep the device in position facing the satellite, the craftsman attached a counterweight in the form of a padlock to each collar.

The herd owners selected one animal from their herds for tagging and the locality focal points (who were also vets) checked that the animal was healthy. In total, 18 devices were fitted to animals (see Table 2). We began tracking the herds during the third week of April and ended tracking the last week of September 2017.

Satellite precipitation estimates

In areas where ground-based rain gauge data are limited, such as West Darfur, satellite precipitation estimates (SPE) are the only available alternative. The SPE from the Tropical Rainfall Monitoring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) program have been shown to be effective in monitoring and mitigating a variety of hydro-meteorological hazards (Huffman, Adler et al. 2007).

The TMPA version we used is non-real-time, quasi-global gridded. Monthly, it merges satellite rainfall

6 When devices were physically attached to the animals.

estimates with gauge data provided at 0.25 × 0.25 degree spatial resolution.[7] We used data from January 1998 to August 2017.

To draw comparisons between the study areas, we used a 10 x 10 km square extracted over each area, which produced 221 pixels (13 x 17) using the TRMM product based on the time-averaged raster. We did this using NASA's Giovanni interface, which allows for easy analysis of satellite imagery over space and time.[8]

Satellite-based vegetation index
Vegetation seasonality is one of the main factors driving livestock mobility in West Darfur. It is imperative therefore to analyze the seasonal evolution of the vegetation cover in the areas that the livestock keepers visit during their annual cycle of movement. We used the NDVI[9] to view inter- and intra-annual vegetation changes and how this influences livestock movements. The NDVI used in this analysis is extracted from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor aboard the Aqua and Terra satellites. The MODIS products we used were 8-day composites at 250 m spatial resolution for 2000 to 2017.

2.5 Limitations

Several practical constraints were experienced in implementing the research, including: identifying suitable tracking technologies; the loss of a number of devices; and working in a sensitive border region.

The selection and design of the GPS tracking device involved defining the required performance criteria and then working with the supplier to develop a suitable product to match those criteria. The device criteria included:

- Store-onboard archival ability;
- Tolerance of extreme climatic and environmental conditions (temperatures up to 50°C, heavy rains, possible submersion in water, and hard scraping against trees and rocks);
- Tamperproof, with no visible lights, sockets, or wires;
- Ability to blend into the environment with no obvious sign of modern technology (for this reason, the device was encased in a locally made leather pouch and collar).

The process of building stakeholder support and obtaining permissions at the state, locality, and community level was very successful, as this process was supported by various local stakeholders and led by the senior personnel from the State Ministry of Livestock.

One limitation of the study is that the research included only male livestock keepers, as it is very rare for women to own livestock due to social barriers. However, women do have a role in watering and looking after sick or young animals, and can own goats. Young girls also look after small numbers of sheep, and there are signs that they are increasingly working as herders, given the absence of young men due to migration.

Another limitation is that the three communities included in this study are not broadly representative, although they do provide case studies of livestock production and management practices that are found in the region. Also, the livestock keepers were selected as examples of how people are coping in an area affected by a range of shocks.

7 Link: https://disc.gsfc.nasa.gov/datasets/TRMM_3B43_7/summary.
8 Link: https://www.nasa.gov/audience/foreducators/9-12/features/giovanni-an-easier-way.html.
9 For more details on NDVI background and analysis in relation to livestock movement, please see Young, Behnke et al., 2016.

3. The livelihoods of livestock keepers

3.1 Livelihood activities: Complementarity and diversification

The two main livelihood activities in the study communities are herding and farming. All except one study participant used this combination of activities. Among those combining these activities, the importance of herding compared to farming varies considerably. The Kulbus livestock keepers are more specialized in farming and are known historically as settled communities, while the El Geneina community is known as nomadic and to specialize in pastoralism. The families began to settle in Telehaya in the 1990s. The one exception was a nomadic[10] pastoralist, whose household does not practice farming (GT3).

Communities try to maintain both activities in a complementary way; as they say, "Everyone should keep his hand on *groon* (horns) and in *jroon* (traditional granary)." For example, a general pattern is that in the beginning of the rainy season people tend to sell some animals to buy agricultural inputs, and after harvest they invest the surplus of their income from farming to buy animals. Moreover, when they lose their herds due to climate shocks or insecurity events, they use their income from farming to slowly rebuild their herds. Also, the accumulation of livestock wealth is considered a means of insurance that can be used during difficult times. For example, KB3's experience showed that when he lost his cattle and sheep during the insecure period in Bir Taweel from 2010 to 2014, he sold some camels that he had far from the region to rebuild the sheep and cattle herds. Therefore, complementarity within and between livelihood activities reduces unexpected pressures.

Pastoralism is associated with a range of different economic activities; for example, work as a broker (*sababi*), livestock trader (*galaji*), or guarantor (*damin*). *Galaji* is the most common. This is the practice of buying, fattening, and selling animals. It can also refer to collecting animals (usually sheep) from livestock keepers after agreeing upon the price, taking the animals to the market, selling them, and then paying the owners. Communities in Kulbus extend these activities across the border to Chad. For example, KB1 is the guarantor for Kulbus residents who trade livestock in the Chadian markets.

Apart from activities linked to pastoralism and farming, there is a range of new activities pastoralist households are diversifying into. For example, KB3 mentioned that one of his sons worked in traditional gold mining. Last year when he returned from the mines, he was able to purchase a car that he is currently using for commercial transport between weekly markets in the area. In the case of GT2, two of his sons bought a car in 2007, and they are working transporting people and goods between markets. Some livestock keepers also practice small businesses; KB4 has a small business selling water on market days in Kulbus and Bir Taweel. Migration to Europe provides indirect support to livestock herds by contributing to family expenses, thus minimizing livestock sales. For example, KB1's brother migrated to Norway in 2010 as an asylum seeker. Since then, he supports the family with regular remittances.

3.2 Livestock ownership

The most common livestock species currently reared by the sample livestock keepers is sheep, followed by cattle and then camels. Goats are also present,

10 In this report the term "nomadic" refers to the livestock keepers who move year-round with their animals looking for pasture and water without having a permanent place of residence.

but male livestock keepers consider them a less important species in terms of wealth.[11] They always combine a small number of goats with sheep herds. Table 3 shows the herd species and size[12] that the recruited livestock keepers own. It is clear from the herd size and number of herds that sheep are the most common species. The common practice is to own two species: sheep and cattle. However, there are cases where livestock keepers own three species or only one species. GT3, who is still nomadic and is not practicing farming, is the only one among our livestock keepers who owned all three species. GT2, on the other hand, specializes in camels. He commented, "I am aware that sheep are easy to manage compared to camels and nowadays are easier to sell in markets. But I am more than eighty years of age and it is difficult for me and my mode of work."

Key informants described changes in the perceptions and attitudes of livestock keepers on livestock ownership in the area. Historically, the most common livestock species in El Geneina (Telehaya) and Kulbus (Goshosh and Bir Taweel) were camels and cattle, respectively, followed by sheep. Now sheep are the most common in both areas. They explain that sheep production is efficient in terms of quick breeding and economic value. The trend of rearing sheep more than other species began in the area in the late 1980s and the early 1990s. This change is mainly due to the market incentives linked to flourishing sheep exports. Further, livestock keepers affected by persistent droughts and famine in the early eighties say that they prefer to concentrate on sheep when rebuilding their herds for the reasons above.

As sheep herds increase, cattle and camel rearing are diminishing, as it has become more challenging to rear them. Livestock keepers mentioned that the main challenge to rearing of cattle is the lack of sufficient water sources at a suitable distance from the pastureland. Further, sometimes insecurity requires them to keep their cattle herds in remote, yet secure, places far from water sources. They explained that cattle cannot survive for more than

Table 3. Herd species and size owned by recruited livestock keepers.

Locality	Community	Code	Sheep	Cattle	Camel
El Geneina	Telehaya	GT1	Medium	Small	
		GT2			Large
		GT3	Large	Medium	Medium
		GT4	Medium	Small	
		GT5	Large	Small	
Kulbus	Bir Taweel	KB1	Large	Small	
		KB2		Small	
		KB3	Large	Medium	
		KB4	Medium	Small	
	Goshosh	KG1	Medium	Small	
		KG2	Small	Small	
		KG3	Large	Medium	
		KG4	Small	Small	

11 However, goats are the main source of milk, meat, and hides used by the family and are therefore important for food security. They are kept close to the household and usually managed by women and children.

12 Approximate herd sizes according to a key informant are: sheep: large 200–300, medium 120–200, small 80–120 heads; cattle: large 100–150, medium 80–100, small 50–80 heads; camels: large 100–120, medium 80–100, small 50–80 heads.

two days without water, while sheep can last three days. The challenges for camels are different. The main challenge facing camel herding is the need for wide pastures and long-distance movements. At the time of the study, livestock keepers reported that looking for pastureland in more remote, distant areas is becoming dangerous and a real threat to the herd and herders. GT2 mentioned that he reduced the annual long cycle of movement to short-distance movement since the emergence of insecurity in 2003. He estimated the current annual cycle of his camel herd to be about one-third of the distance the herd previously moved. KB2 stated that during the time of armed robbery in early 1990s, communities in his area lost a lot of men in *fazaa* (mobilization of men of fighting age to recover stolen livestock). Similarly, KB1 mentioned that armed robbery is the main reason he stopped raising camels.

Table 4 depicts how the livestock keepers ranked the benefits and characteristics of livestock species for particular activities. This ranking clearly shows that each livestock species is preferred for different reasons, which reflects the practice of keeping more than one species in hand. Camel are the most culturally preferred in the area. However, commercially sheep sell the quickest in markets and are therefore the species sold when money is needed urgently. However, they are also most vulnerable to disease and therefore are the costliest in terms of medical treatment and vaccinations. When a large amount of money is needed for social events and ceremonies, such as wedding or *haj* (the pilgrimage to Mecca), livestock keepers sell camels. Goat rearing is mostly the responsibility of women, and goats are sold to meet small expenses.

3.3 Strategies to improve efficiency and cost effectiveness

To reduce the cost and labor needed for herding, some livestock keepers who own a small number of heads combine their animals into one herd. This practice makes mobility more feasible. KG4 mentioned that he and three other livestock keepers started combining their cattle herds in 1994. All of them live in Goshosh and rely on household labor to look after the combined herd. Each family is responsible for a specific period. In the dry season when the milk is insufficient to be divided up between all owners, they benefit from it in turns. The four livestock keepers also own sheep herds, but these are large enough that the herder looks after his own sheep herd.

KB4 and his cousin are another example of a combined herd. In 2000, they combined their sheep

Table 4. Ranking of some livestock criteria according to the perceptions of the recruited livestock keepers.

Criteria	**Ranking of livestock species**			
Rank order	*1st*	*2nd*	*3rd*	*4th*
Culturally preferred	Camel	Sheep	Cattle	
Milk	Camel	Goat	Cattle	Sheep
Drought resistance	Camel	Goat	Sheep	Cattle
Urgent/quick need for money	Sheep	Goat		
Expenses needed for serious illness	Camel	Cattle		
Resistance to diseases	Camel	Goat	Cattle	Sheep
Social events and ceremonies (e.g., wedding)	Camel	Cattle	Sheep	
Meat	Camel	Goat	Sheep	Cattle
Normal family expenses	Goat	Sheep		
Women's small expenses	Goat			

Note: This is an averaging of the ranks assigned by all livestock keepers and is based on their general perceptions.

herds. KB4 currently lives in Kulbus and is mainly engaged in farming. All of his children go to school, and none of his family members herd or farm. His cousin lives in El Geneina and works as a veterinary assistant. Both owners have no time to look after their animals, so they hired a herder, who is paid in kind (from 15 to 20 heads of sheep and goats per year). Because of the high rate of breeding in sheep, they use a tattoo to identify ownership.

3.4 Selling and buying livestock

Selling heads of animals is done throughout the year to meet family expenses, herd expenses, and other specific needs, such as buying farming inputs. However, there are times when sales are more common, such as late *seif* to buy fodder or in *rushash* to buy agricultural inputs. Occasionally, livestock keepers sell animals for specific ceremonies and social events such as weddings.

There are many reasons that livestock keepers may be forced to sell a significant proportion of their livestock. For example, access to water sources is the main challenge during periods of insecurity. Therefore, many livestock keepers reduce the size of their herds. KB1 declared that he sold 15 heads of cattle and 60 heads of sheep in 2003 due to insecurity. He acknowledged that prices were low, and he had to sell the animals in markets he could safely trade in such as Seraf Omra, which is far from his area. He used the money from these livestock sales to build a house in Kulbus. Currently, students in his family who are attending school in Kulbus use this house. Another factor that forces livestock keepers to reduce their herds is dry years. KB4 said that in 2014 he sold about 12 and 30 older heads of cattle and sheep, respectively. At such times, the prices are usually low, but the older or weak animals could not bear to walk long distances to water sources or to search for far-off pasture. He spent the money to buy fodder—hay, crop straw, and concentrates—to feed the rest of the herd.

Livestock keepers tend to use the money from selling surplus crops in good harvest years and income from other marginal activities to rebuild their herds. Livestock keepers explained that the best times to buy livestock are *rushash* and *hasad* (harvest time). In Telehaya *rushash* is the most common time to buy, and in Kulbus the most common time is *hasad*. Both communities prefer to buy sheep. However, those who have less money buy goats. Livestock keepers buy males for commercial purposes (e.g., *galaja*), and they buy females to build their herd. They generally buy livestock in the weekly market.

3.5 Farming

Farming is practiced as subsistence farming to secure food, generally leaving no surplus to be marketed. The two major farming systems are rainy season and dry season cultivation. A third system is horticultural gardens, which are normally located near *wadis* during rainy and dry seasons. See Box 3 for an example of a livestock keeper cultivating a horticultural garden. The rainy season cultivation is practiced on *goz* (sandy) soil. Cultivation normally starts around mid-July, and harvest takes place in December, or January of the next year. Formerly, farming in *goz* soil was practiced in the form of shifting cultivation, in which farmers cultivate a piece of land for several seasons until its yield drops. Then they would shift to new land. Informants explained that shifting cultivation stopped in the mid-1990s due to the influx of new settlers fleeing insecurity. Because the sandy goz soils cannot bear continuous cultivation, farmers now use a number of practices to maintain the fertility of land that they must continuously farm. Examples of these practices are crop rotation, land fallowing, and manuring with animal dung. Crop rotation is changing the type of crop cultivated on the same patch of land (e.g., cultivating millet or sorghum for a few years and then changing to groundnuts). Groundnuts are a leguminous crop that fix nitrogen in the soil. If the soil is severely degraded, they give the land a period of two to three seasons of rest as fallow. Manuring takes place when animals graze on crop residue during *talaig*. These soil conservation measures are mainly practiced by communities in Kulbus, who are experienced or specialized in farming. In Telehaya where farming is relatively new, they mostly rely on manuring.

Millet and sorghum are the staple crops and are cultivated during the rainy season. These farms occupy around half to two-thirds of cultivated land.

Box 2. Organization and division of roles of farming activities in polygamous households.

The agricultural activity in polygamous households in Telehaya and Kulbus showed that each wife and her children are an independent production unit for rainy season cultivation of *goz* land. Each wife has her own separate piece of land for cultivation, and the man also has his own land. Each of them keeps his/her harvest in separate grain stores. Normally, once each wife finishes cultivating her own land, she will join the other wives to cultivate the husband's land. They will continue in this way for subsequent farming activities, i.e., weeding and harvesting. The wives cultivate crops for consumption, such as millet, sorghum, groundnuts, tomato, and okra. On the husband's farm, they cultivate cash crops such as hibiscus, watermelon, and tomato in addition to millet and sorghum. During the dry season, the whole household generally cultivates one piece of land, under the management of the husband.

In monogamous households, the entire household tends to cultivate one piece of land together during the rainy and dry seasons.

Households also grow groundnuts, which is the main edible oil crop, and okra, which is the major vegetable crop in the area during the rainy season. Other minor crops sown at this time include cowpea, watermelon, musk melon (*shamam*), and chickpea. If there is a poor yield, some households may cultivate the staple crops again during the dry season to overcome the shortage in household food store. Groundnuts, okra, and watermelon can be marketed. Rainy season farms of the livestock keepers range from 4 to 22 *mukhamas* (unit of farm size).[13] If the head of the household has more than one wife, normally each wife will have a piece of *goz* land. Box 2 elaborates the organization and division of roles in polygamous households.

Dry season cultivation is typically practiced after the *wadi* recedes. The cultivation usually begins around late October, with the harvest falling around early March. Households cultivate the fertile loamy clay soil in the *wadi* that was flooded by water. The development of the crops depends on the retention of moisture in the soil. Main crops cultivated in the *wadi* are vegetables such as okra, tomato, onion, and cowpea. Additionally, people cultivate a limited amount of wild cucumber (*tibish*) and sweet sorghum (*ankoleeb*). If the harvest was not good during the rainy season, households may also cultivate cereals. Compared to rainy season cultivation in *goz* soil, the land area cultivated in dry season cultivation is much smaller, but it is highly productive. The land ownership in the *wadi* is from two to seven *mukhamas*.

Farming is relatively new for livestock keepers in Telehaya. Some started to farm in the late 1990s, while others began in the early 2000s. Both dates align with pastoralists settling due to insecurity. They cultivate a limited number of crops, mainly millet, sorghum, and okra. In good rainy seasons, they might add groundnuts. None of the recruited livestock keepers practice dry season farming along the *wadi*.

Box 3. Livestock keepers cultivating a horticultural garden as well as rainy and dry season farms.

One livestock keeper in Kulbus (KG3) owns a horticultural garden. This type of garden, one *mukhamas* in size, is irrigated from deep wells using mechanical pumps to extract water. In his horticultural garden, KG3 has citrus trees and plants various vegetables, such as tomato, onion, chickpea, and cucumber. He also owns rainy season and dry season farms.

13 *mukhamas* = 1.8 acres or 0.73 hectares.

Box 4. Balancing household and hired labor and education of children, including girls.

KB3 has a big family consisting of three wives and 21 children. He relies on household members and hired laborers for farming and herding. Children in school also work on rainy season goz farming during weekends and school holidays. His three wives and their preschool children are responsible for dry season farming. Concerning livestock herding, each year he takes one of his daughters out of school. The following year he sends her back to school, and takes out another daughter to take her place. His daughters are responsible for looking after the cattle herd. He hired a young boy to look after the sheep herd, under his supervision.

KB4 is an exceptional case. None of his family members work with him in farming or herding since he moved his family from Bir Taweel (village) to Kulbus (town) in 2010 due to the insecurity situation. He sends all his children to school, and he relies totally on hired laborers.

The Kulbus communities have specialized in farming for centuries. They practice rainfed faming in the *goz* soil and farm land in the *wadi* during the dry season. The *wadi* soil is very fertile due to annual flooding that brings new soil. They cultivate a wide range of crops, including some cash crops such as watermelon.

3.6 Roles and responsibilities of household members

Herding and farming are labor-intensive activities. The livestock keepers generally rely on household members to take on different responsibilities related to their livelihood activities, with a minimum amount of external labor. The division of roles depends mainly on the household make-up and the household head's attitude. Age and gender are taken into account for some tasks. One important recent change in attitudes in all communities is that people are more willing to send their children to school. This is especially the case among those who were displaced to or settled in areas where there are schools. However, boys are more typically sent to school than are girls. Sending children to school is more common in the Kulbus area than in the Telehaya area we studied (see Box 4).

When farming activities start at the beginning of the rainy season, most household members are busy preparing the land and sowing seeds, so they minimize the herding labor. When the rains are established and when there are fears that their herds could damage others' crops, the male members of the family move with the herd to remote places to find pasture and avoid damaging crops. The women stay in the farming area to take care of the crops. Small numbers of milking heads are normally left with the women. During the harvest time, some of the men might return to join the women and help with the harvest or they might hire laborers as KB1 and KG4 do. Normally, the head of the household moves between the two groups. Weeding is one of most labor-intensive farming activities and must be carried out at the right time. Therefore, *nafeer* (calling on the community for help with specific work) is still practiced in some communities such as Bir Taweel and Goshosh.

During the dry season—*shita* and *seif*—we saw examples of "self-herding" cattle herds, meaning they have no herder looking after them for the entire time they are grazing. Instead, livestock keepers meet up with their herds every two or three days at the watering point, according to the watering frequency or schedule, to check that the herd is complete and healthy. This self-herding obviously minimizes the labor demands. When practicing self-herding, households keep the milking animals and the small calves in a *zariba* (enclosure to keep animals inside) in the camp (*farig*).

Division of roles and responsibilities for herding and rainy season farming across seasons shows marked differences in labor requirements for the two main livelihood activities across seasons. During *seif*, virtually all household members are focused on the livestock. During *rushash* and the first

part of the *kharif*, household labor has to be split between farming activities and searching for pasture. However, most of the household labor force will be dedicated to farming activities. Once again during *deret* and *hasad* most of the household will focus on farming. If the harvest is not completed before the *talaig*, the harvest will be at risk of damage by grazing livestock.

4. Livestock management: Seasonal imperatives and herding

4.1 Overview of the annual cycle of movement

Livestock keepers design and manage the annual cycle of movement for their livestock in a way that assures and guarantees optimum access to the required pastoralist resources that maintain and sustain the herd. Figure 6 depicts the grazing zones utilized by livestock keepers: home area, close grazing land, and distant grazing land. Figure 7 shows the number of days spent by the recruited herds within each grazing zone during the study period (May 2016–April 2017). Annex 2 shows the actual number of days by herd and zone.

Figure 6. Schematic of the grazing zones visited by the recruited livestock keepers in their annual movement.

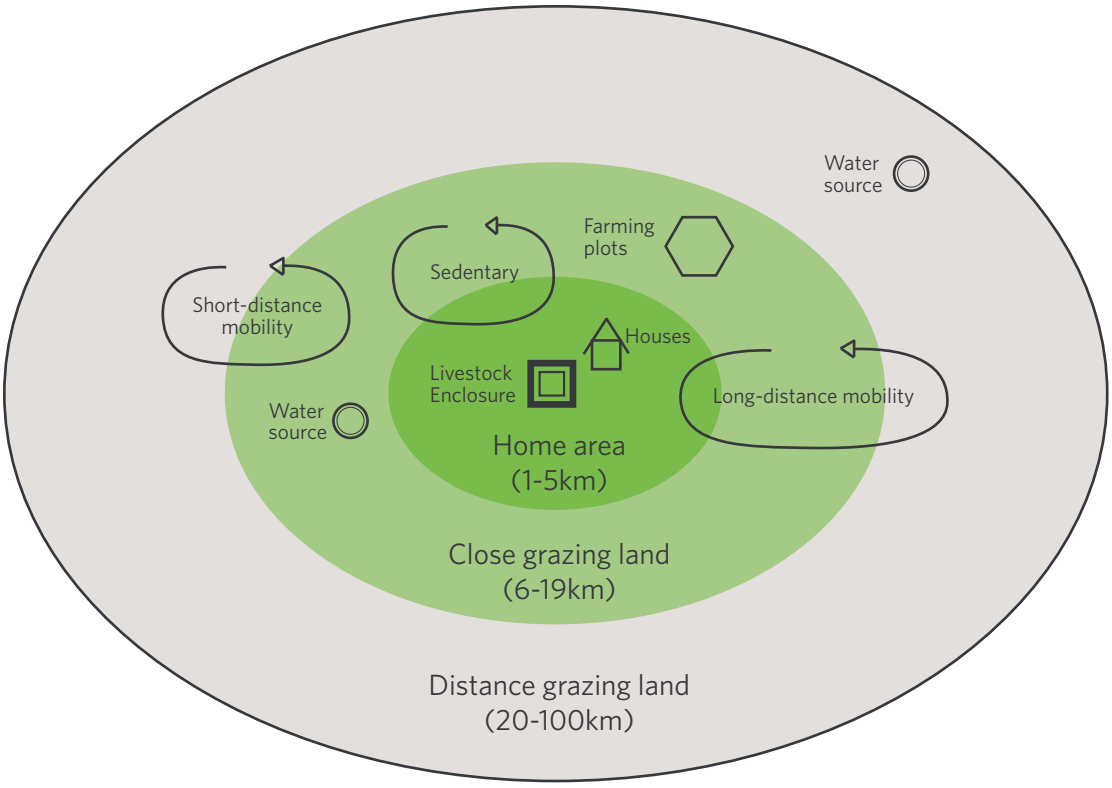
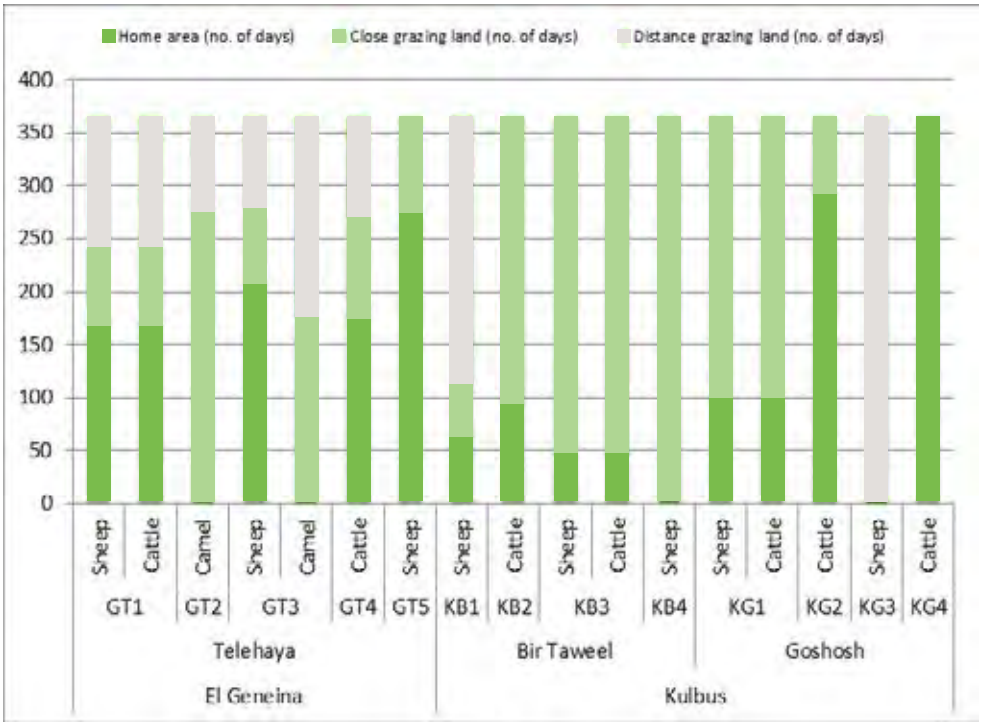


Figure 7. Total number of days spent by recruited livestock herds in different grazing zones during the study period (May 2016–April 2017).



Herder codes: 1st letter: G–Geneina, K–Kulbus; 2nd letter: T–Telehaya, B–Bir Taweel, G–Goshosh; 3rd numeral: herder number.

4.1.1 Long-distance mobility

The livestock keepers who plan for long-distance mobility divided their annual cycle of movement among three grazing zones. They spend *seif, rushash,* and *kharif*[14] in the distant grazing land (located to the west for the Kulbus livestock keepers, and to the north for those from Telehaya), where the animals are managed by mature male members of the household. This mode of mobility is practiced mainly by livestock keepers from Telehaya (see Figure 7). They spent from a quarter to half of the total annual cycle in the distant land. For example, GT1's cattle and sheep herds spent one-third of their annual cycle in this zone. He said that lack of water for animals was the principal factor pushing him and other livestock keepers to reduce their time in the distant northern area despite there being good fodder still available. KG3 is the only livestock keeper from Kulbus to go to the distant grazing land.

As harvest approaches, livestock keepers proceed to their home area to utilize the *talaig*. They stay there for all of *shita*, and the herd grazes on crop residues and pastures around the village. During this time, young boys and girls look after the herd.

4.1.2 Short-distance mobility

Short-distance mobility, concentrated in the close grazing zone, is the most popular grazing zone in both communities and in the state generally. It is an adapted version of the long-distance mobility in response to insecurity. Overall, livestock keepers spend about 45% of their annual cycle in this zone. Normally, the whole herd remains away from home,

14 Based on interviews with livestock keepers and weekly phone calls, the tracking season in 2017 could be divided as follows: *seif* from the start of tracking to May 15, *rushash* from May 16 to June 15, and *kharif* from June 16 to end of tracking.

except for a few heads left at home for milking purposes. In this short-distance zone, mature and young male household members are responsible for the herds. GT2's camel herd spends three-quarters of the annual cycle in this zone, while KB4's cattle herd spends the whole year in this zone. According to the livestock keepers, water sources are sufficient in this zone, but the pasture is rapidly deteriorating due to a high concentration of livestock, especially in areas around watering places. This is the opposite situation of the one found in the distant grazing land.

4.1.3 Sedentary system of mobility

Kulbus communities reported using a more sedentary system of livestock mobility, in which livestock grazing is very restricted and confined between the home area (village or *damra* and the surrounding area throughout the year. This system is practiced by settled communities who are primarily farmers and own few livestock (some practice *serha*—see Box 5 for an explanation of *serha*). Usually young boys are girls are responsible for the herds. However, some livestock keepers also practice this system during periods of conflict. Many in our study continue to do so to avoid livestock looting. Livestock keepers rely on pastures and the forests around the village, and they also graze crop residues after the *talaig*. They water their herd from the water sources around the village such as hand pumps and electric pumps, which are generally used to irrigate horticultural crops. For example, KG2 is heavily engaged in farming, and his cattle herd spend 80% of the year in his village. He takes them away at two times: when the crops are established in the middle of *kharif* and once again in late *seif* when there is a lack of fodder around the village. The small combined herd of KG4 spends the whole year in the vicinity of the village.

4.1.4 Decision-making related to herd management

The main factors that traditionally influenced the decisions of the recruited livestock keepers related to the design and annual cycle of movements are: livestock species, herd size, and the livestock keeper's engagement in farming.

There are two newer factors that put pressure on livestock keepers' mobility today: overgrazing of pastures near their homes and surrounding areas, and the threat of insecurity and looting if they venture farther afield. The deterioration of rangeland near their settlements means they have to look for better pastures in more remote rangelands. At the same time, the insecurity in the region is forcing them to stay near their homes, where they have support from their social networks. They mentioned that they are more vulnerable to theft and at risk of losing livestock in areas where they have no or few social contacts. Key informants from Goshosh mentioned that this restricted mobility, especially during *mahal*, is causing some livestock keepers to drop out of the system and sell off their animals. The general outcome of the situation is that seasonal transhumance, or pastoralist livestock migration patterns, is changing from long- distance to short-distance cycles.

There are clear differences in the annual cycle of movement patterns between livestock keepers in Telehaya and Kulbus (see Figure 9). These differences reflect their main livelihood activity, which is linked to whether they specialize more in farming or in livestock rearing. The two specializations have different ways and means of conducting their annual cycle of movement. According to the description given by livestock keepers, livestock keepers from Telehaya tend to visit the same areas each year, while those from Kulbus

Box 5. *Serha*—the practice of combining small numbers of livestock for herding by a hired herder.

Serha is a livestock management system in which several livestock keepers combine their herds and hire a pastoralist herder to bring the combined herd to the area surrounding the village, such as nearby rangeland and return the animals back to their owner late in the evening. During *talaig*, these herds graze on free crop residue after the harvest is complete.

are more flexible and frequently change where they take their herds from year to year.

4.2 Changing from fully to partially mobile and from longer to shorter distances

As described above, the Kulbus communities specialize in farming as their main occupation and also rear livestock. In contrast, the Teleyaha community traditionally specialized in nomadic pastoralism and have recently settled and therefore have also started farming, although part of the household continues to migrate seasonally with the herd. Telehaya livestock keepers described their motivations for settling or for staying mobile:

- GT1 said that he was totally nomadic, but due to the insecurity situation, in 2003 he settled near Telehaya and started farming. In 2014, he sent two of his sons to school.
- GT4 partially settled in Alimbo (a *damra* (established nomadic settlement usually adjacent to an established village) near Telehaya) in 1998 due to the threat of armed robbery (when mobile). He also began farming.
- GT3 is the only totally nomadic livestock keeper in the study. In Figure 11, although it appears his herd spends time close to home, this home is a temporary nomadic encampment (*farig*). With the exception of *seif*, his household and the herds are on the move all year round. During *seif,* he remains in the proximity of water points, but still moves camp every six to seven weeks to find better pasture.
- GT2 and GT3 described that their camel herds cover longer distances than cattle and sheep herds. However, completing such long journeys is becoming challenging due to insecurity issues and lack of water sources in remote northern rangelands along the border with North Darfur.

The Kulbus communities have also restricted their herds' movements because of the deterioration in security conditions. KB1 mentioned that after the emergence of problems of insecurity in 2004 in Bir Taweel, he changed his annual cycle of movement considerably to a smaller area and spent more time closer to home (Figure 9 and 10). Previously, his herd movement extended from Jebel Moon in the northeast during *seif* to Abter in the northwest during *kharif*. Nowadays, he spends *seif* in Kamni, which is 40 km from Jebel Moon, and the rainy season in Bir Taweel, which is his home. The diameter of his current annual cycle of movement is about 15 km. Others have restricted their movements similarly. KG4 said that in recent years he tends to practice very limited mobility. Throughout the year, he keeps his sheep herd around his village in the range of 2–5 km during the day, and overnight he brings them inside the village, which is more like the sedentary system of mobility.

4.3 Daily routine and activities

Livestock herding is intensive work, especially during *seif*, when it consumes the entire day and may extend to nighttime for some species.

The early morning begins with milking. Milking takes around one hour during *seif* and *shita* when milk yield is low. It extends approximately two hours during *rushash* and *kharif* when milk production is high and there are more animals to be milked. Milking contributes to the household nutrition when the herd is nearby.

After milking, the herd is sent out for grazing and will return in the late evening. Animals do not graze in the early morning when pasture is still wet, because livestock keepers believe this causes livestock diseases. Once the dew has evaporated, they go to graze their animals. This perception and practice was also reported elsewhere in Sudan (Young, Sulieman et al. 2013). The herd takes rest (*magela*) around midday to avoid high temperatures. The radius of grazing from the camping place is relatively short during *rushash* and *kharif*, up to 3 km, and comparatively long during *seif* and *shita*, around 5 km and maybe more.

On the day that the herd is taken for watering, movement starts in the direction of the water source. If the water source is far, the herd overnights at the halfway point. The distance can be up to 25 km. Watering frequencies differ between species and seasons. During rushash and kharif, livestock drink

Figure 8. Group of women watering animals from a well.

from surface water ponds in depressions. During *shita*, cattle and sheep are watered every three to four days and in *seif*, every three days. Camels are taken to water sources every ten days in *shita* and every eight days in *seif*. GT2 mentioned that during *seif* he mixes *atroon* (a type of salt) with the water because the fodder is of low nutritional value. When the water source is near the village, women and young boys and girls water the livestock (see Figure 8).

Another session of milking may be carried out in evening when the herd has returned to its overnight place. When the herd is remote, only a few animals will be milked. When there are no herders with the herd during the dry season, the cattle will not be milked. For example, KG3 does not milk his cows; instead, his family relies on goat milk. Sheep milk is the least desirable type of milk (see Table 4). Therefore, livestock keepers may not milk the sheep when they are away from home, but rather rely on milk from goats associated with the sheep herd.

Nighttime grazing (*serba*) is very common among sheep livestock keepers during *seif* and to some degree in *shita* and early *rushash*. Grazing at night allows the herder to extend the grazing time in cooler conditions. Coming from a pastoralist background, the community from Telehaya showed more interest in *serba*. However, some livestock keepers such as KB1 and KG3 in Kulbus are doing the same. These activities clearly indicate that livestock keepers try to maximize opportunities and avoid hazards. This daily routine is flexible and changes across seasons.

Compared to the other species, sheep need more intensive supervision. In order to make sheep herding more efficient, livestock keepers integrate a few heads of goats with the sheep herd. Goats are known to walk more quickly than do sheep. They also run or quickly flee from risks such as looting or predators. Camels need intensive supervision because of the wide distances they cover during grazing and browsing.

4.4 Herds splitting

Livestock keepers who own more than one livestock species ideally try to keep their different herds adjacent to each other, assuming that the resources and conditions required by the different species are available in the area. However, such optimum conditions are rarely the case, especially in areas where resources are variable, such as West Darfur. Thus, it is often more efficient and conducive for production to split the herd by species and manage them separately.

Herds are split for additional reasons as well: household characteristics (age and gender); labor availability; needs of other livelihood activities; and the threat of looting and insecurity. Livestock keepers must take into account the seasonal dimension of these factors.

Box 6. Examples of trade-offs in the management of more than one species and splitting herds.

TGT3 mentioned that during *kharif* he brings the three species he owns together in one place, because the water and pasture are of excellent quality and quantity. However, the three herds maintain some space between them to allow room for grazing (for map, see Figure 18).

This year, GT1 separated his sheep and cattle herds during *kharif*, which is not his common practice. He did so because he was engaged more in *galaja* this year.

GT3 said that during *rushash* and the first half *kharif*, he keeps the three species (camel, sheep, and cattle) together. Towards the second half of *kharif*, one of his sons takes the camel herd about 90 km farther north for two reasons: to avoid damaging crops and to find good pasture (see Figure 18). For his sheep and cattle herds, he targets a wide, hilly area that is not suitable for farming but has good fodder. He and the rest of the family stay with the sheep and cattle herds.

During *seif*, he distributes his herds according to the distance to water sources. The sheep stay nearest to the water sources, followed by the cattle and finally the camel. He camps with his family near the sheep herd (see Figure 11).

KB3 keeps his sheep and cattle herds in one place throughout the year. He might separate them for a short period during *rushash* when resources are scant and fragmented. He leaves his herd throughout the year in an area where there is no intensive farming, but there is sufficient fodder (see Figure 16).

KG1 said that he separates his sheep from his cattle when there is insecurity or worries about looting. He left his sheep herd in a secure place adjacent to his home area, because sheep move slowly, and they are not able to escape trouble efficiently. He moved with his cattle herd within the close grazing lands.

Thus, pastoralists employ opportunistic grazing management strategies that balance the complex trade-offs between the needs of the different species with the environmental variability, availability of labor, and risks of looting and insecurity. Examples of these trade-offs are given in Box 6.

5. Understanding pastoralist mobility: A spatial and temporal analysis

5.1. Livestock tracking

This section presents case examples of seasonal migration based on GPS data, combined with qualitative data and field observations, to provide an empirical record of pastoralist mobility and demonstrate its potential. As we have seen, the recent history of regional insecurity has severely restricted livestock mobility and impeded livestock keepers' ability to fully explore and exploit the variable natural resources in the area. The following cases also show that the livestock keeper management strategies ensure the timely utilization of the accessible grazing resources in harmonization with the non-equilibrium nature of the environment. Besides the main strategy of shifting and reducing movement, livestock keepers have also adopted new herding mechanisms in their attempt to maintain the resilience of their livelihood systems.

The GPS records in this study did not cover the whole annual cycle of movement. GPS tracking started in the third week of April and ended the last week of September 2017. Therefore, the description of movement is for *seif, rushash*, and *kharif* seasons.

5.2 Livestock movement territories in West Darfur: The social and physical dimensions

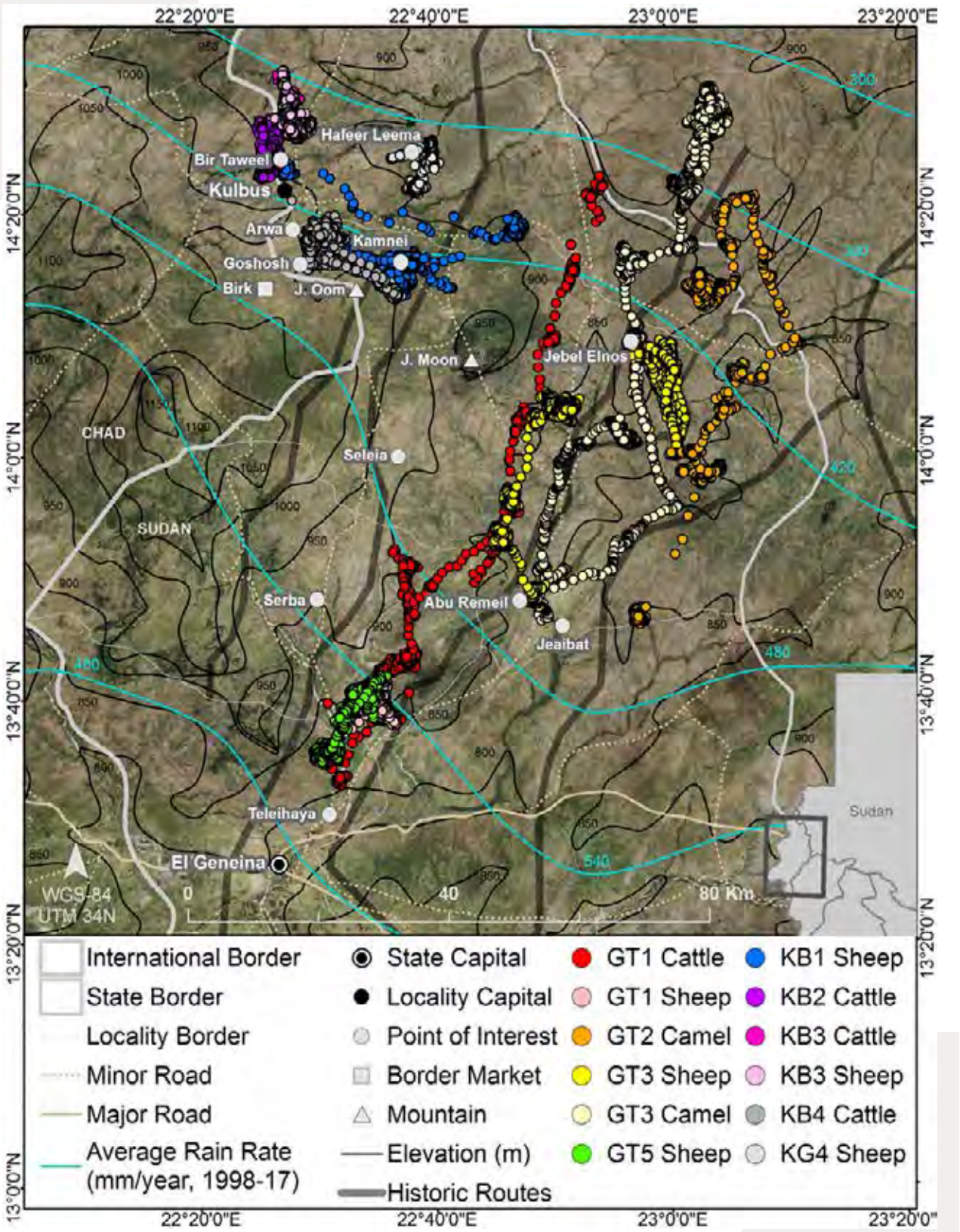
During the six months of the GPS tracking, the recruited livestock herds covered four localities in West Darfur State, and also entered North Darfur State during kharif. The spatial and temporal distributions of livestock herds and the territories visited during the tracking period are shown in Figure 9. This movement is determined by the availability of grazing and water resources, and security. Secure access to grazing areas is influenced by the local political economy, conflict dynamics, and social relations between pastoralists and the local residents.

5.2.1 Livestock keepers from Telehaya, El Geneina Locality

The cardinal direction of movement of livestock keepers from Telehaya is north to south. Their northward movement tracks roughly in parallel with the two major historical livestock migration routes (Figure 9). During the field visits, we observed that although most of these routes were actually open, some parts are blocked by cultivation (practiced by long-standing settled farmers and newly settled nomadic livestock keepers). Historically, this area is the one where the Telehaya livestock keepers moved around when they were nomadic. This is confirmed by reports that former nomads prefer to settle in areas where they previously grazed their livestock and migrated through (Dongmo, Vall et al. 2012). The Telehaya livestock keepers started to settle by establishing *damra* located on the outskirts of established villages where they have connections such as ethnicity or customary linkages.

The annual cycle of movement for this Telehaya group extended for about 120 km south to north. In *rushash*, most livestock keepers started from their home and moved north. However, some livestock

Figure 9. Movements of the recruited livestock keepers in West Darfur during the tracking period.



keepers started their annual migration by first moving south to areas around El Geneina. There they met the advancing rain and took advantage of the new grass earlier than if they had waited for it to arrive in Telehaya. The northern part of this journey took camel herds in particular as far as Wadi Aradeib in North Darfur (see Figure 1 for map).

5.2.2 Livestock keepers from Kulbus

The mobility of livestock keepers from both Kulbus communities (Bir Taweel and Goshosh) is circular and centered around their areas of residence. This closer proximity of livestock herds to residences reflects the lifestyle and traditions of long-established settled communities that are engaged heavily in farming and also practice other economic activities. In the course of the annual cycle of movement, these livestock keepers spend most of their time in the close grazing land (see Figure 7), particularly during *shita, seif*, and *rushash*. During *kharif*, they bring their herds to their home area where pasture and fodder is available. Doing so also allows them to easily divide their household labor between farming and herding activities. As the crops mature, they take their herds to the uncultivated close grazing land to avoid crop damage. None of the Kulbus livestock keepers move to the distant grazing lands.

The circular movement of livestock keepers from Kulbus extends between their homes in the west to lands near Jebel Moon in the east. Deep wells using mechanical pumps in the horticultural gardens around valleys are the main water sources. They also use hand pumps in the vicinity of the villages. Availability and distribution of watering sources in Kulbus are two of the main factors that shape the general pattern of livestock movements and have led the livestock keepers to stay within a certain proximity to the water sources.

5.3 Livestock movement across seasons

Precipitation and its variability are the principal factors determining inter- and intra-annual vegetation dynamics and productivity in the rangeland of West Darfur. In an earlier report, we described the major regional differences in forage quality and quantity in the Sahel, which are fully exploited in the north–south migration patterns (Young, Behnke et al. 2016). There is an inverse relationship between plant productivity (amount of plant growth) and the nutritional value of that productivity (Bremen and de Wit 1983). Therefore, the lesser growth experienced in North Darfur is likely to be of higher value, especially when it is fresh, than the more abundant biomass farther south. This explains in part why it is so beneficial to migrate north away from the regions with more abundant vegetation.

Thus, there are both push and pull environmental factors, and so the resilience of the pastoralist system relies on how livestock keepers respond to the conditions that are inherent in the environment. Consequently, it is important to understand the underlying logic and evidence base of the management decisions taken by livestock keepers to move their herds from place to place across different seasons of the year.

5.3.1 Movement in seif

Seif is the toughest season for livestock keepers and their herds, because it is the driest and hottest period of the year in West Darfur. It is also the longest season. This is reflected in the health conditions of livestock and of the livestock keepers themselves (as observed during this study). The surface pools and puddles that collect during *kharif* have long since dried up. The water table in shallow wells becomes progressively deeper, and the quality of water deteriorates. Therefore, water availability is the main factor limiting livestock movement in *seif*.

The general strategy is to keep each species within reach of water points. The water points are mainly the permanent deep wells equipped with mechanical pumps, which are located along valleys and have been installed by the private sector. Frequency of watering varies according to the species. Camels are watered less frequently than cattle or sheep and so have more freedom or time to move to distant grazing land before returning for watering. Figure 11 shows the example of GT3 who owns sheep, cattle, and camel herds (no data is shown for cattle). During *seif,* he keeps the sheep herd two days' walking distance (about 12 km) from the watering

Figure 10. KB1 pattern of movement across *seif, rushash*, and *kharif*.

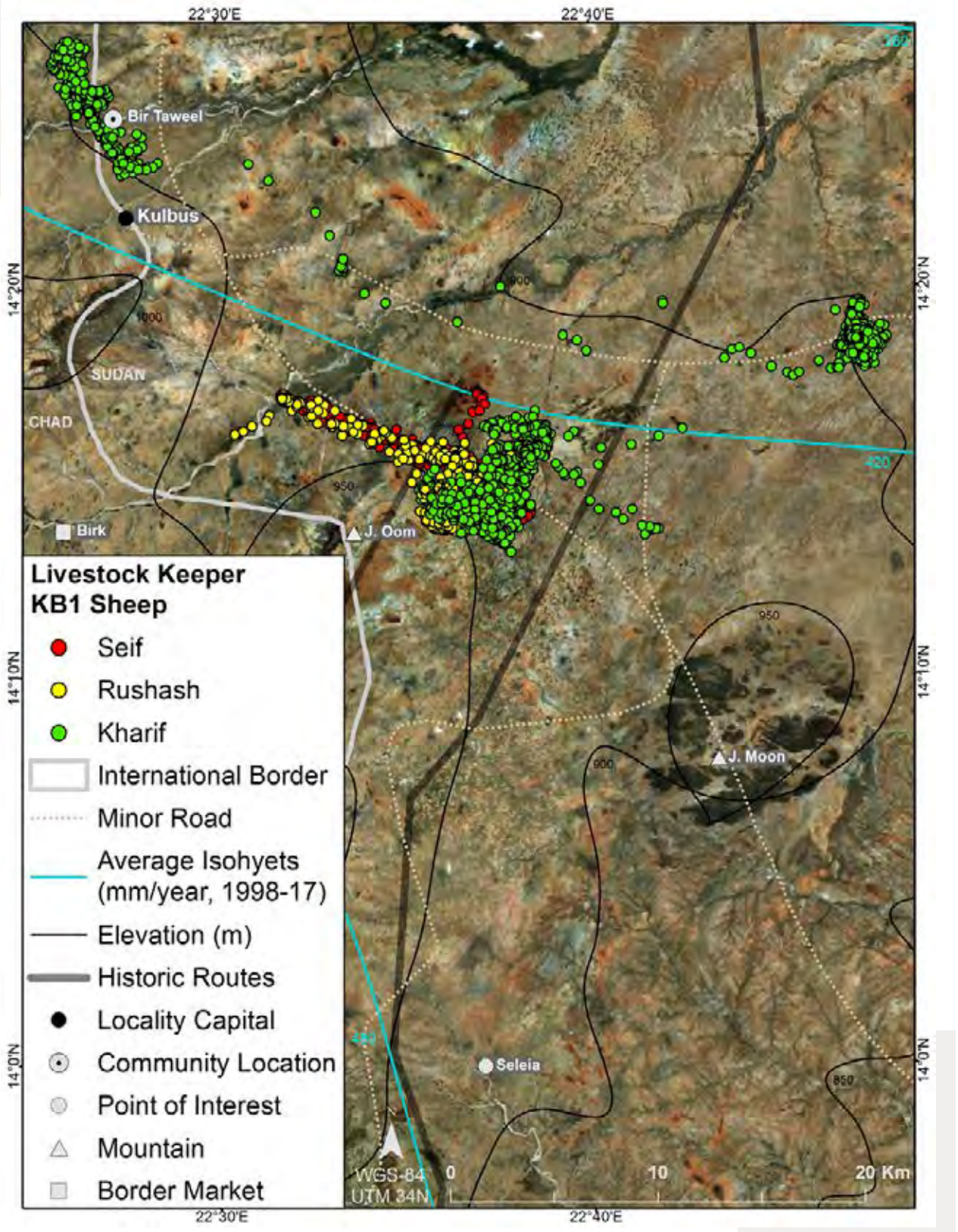


Figure 11. GT3's movement of sheep and camels together during the dry season.

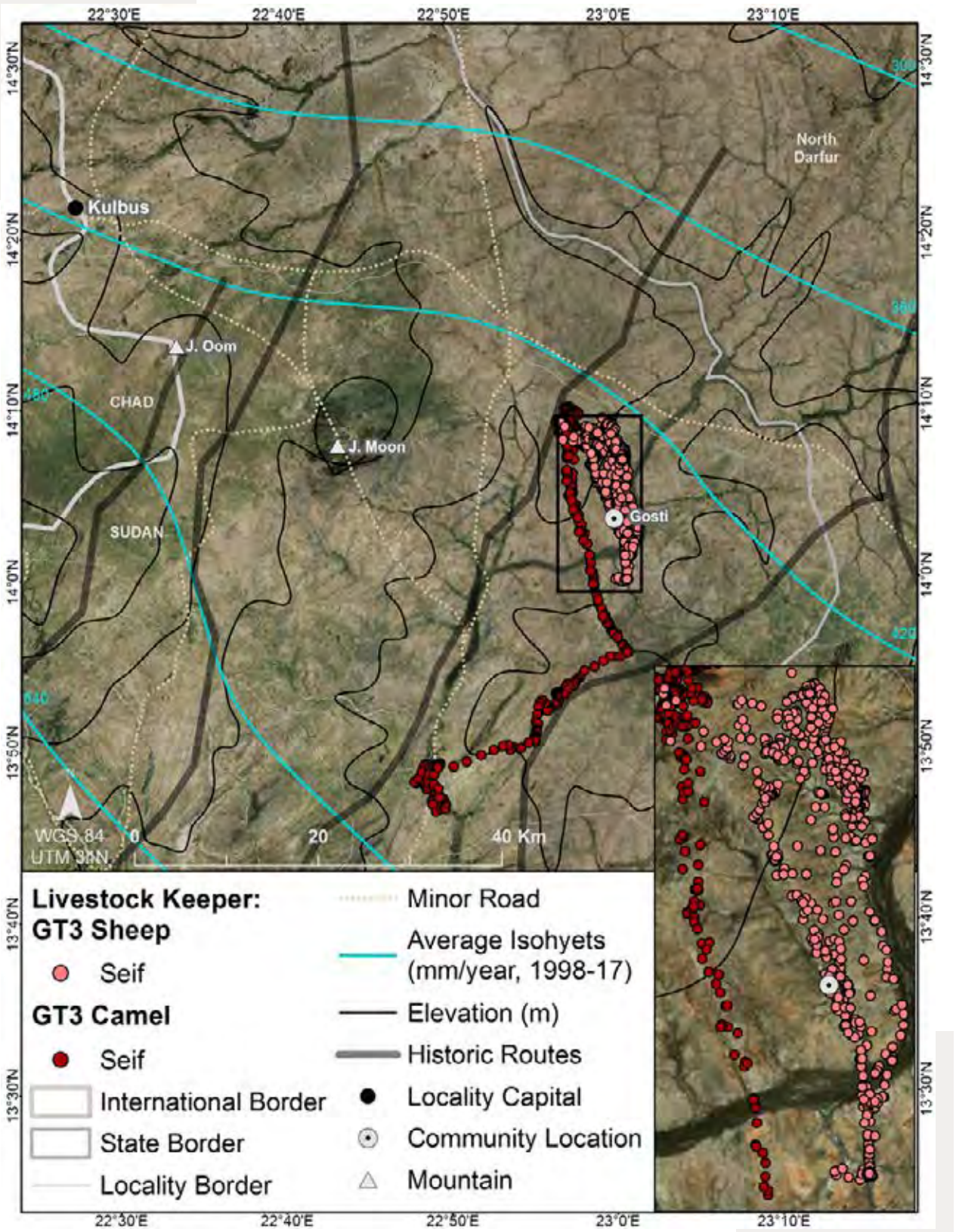
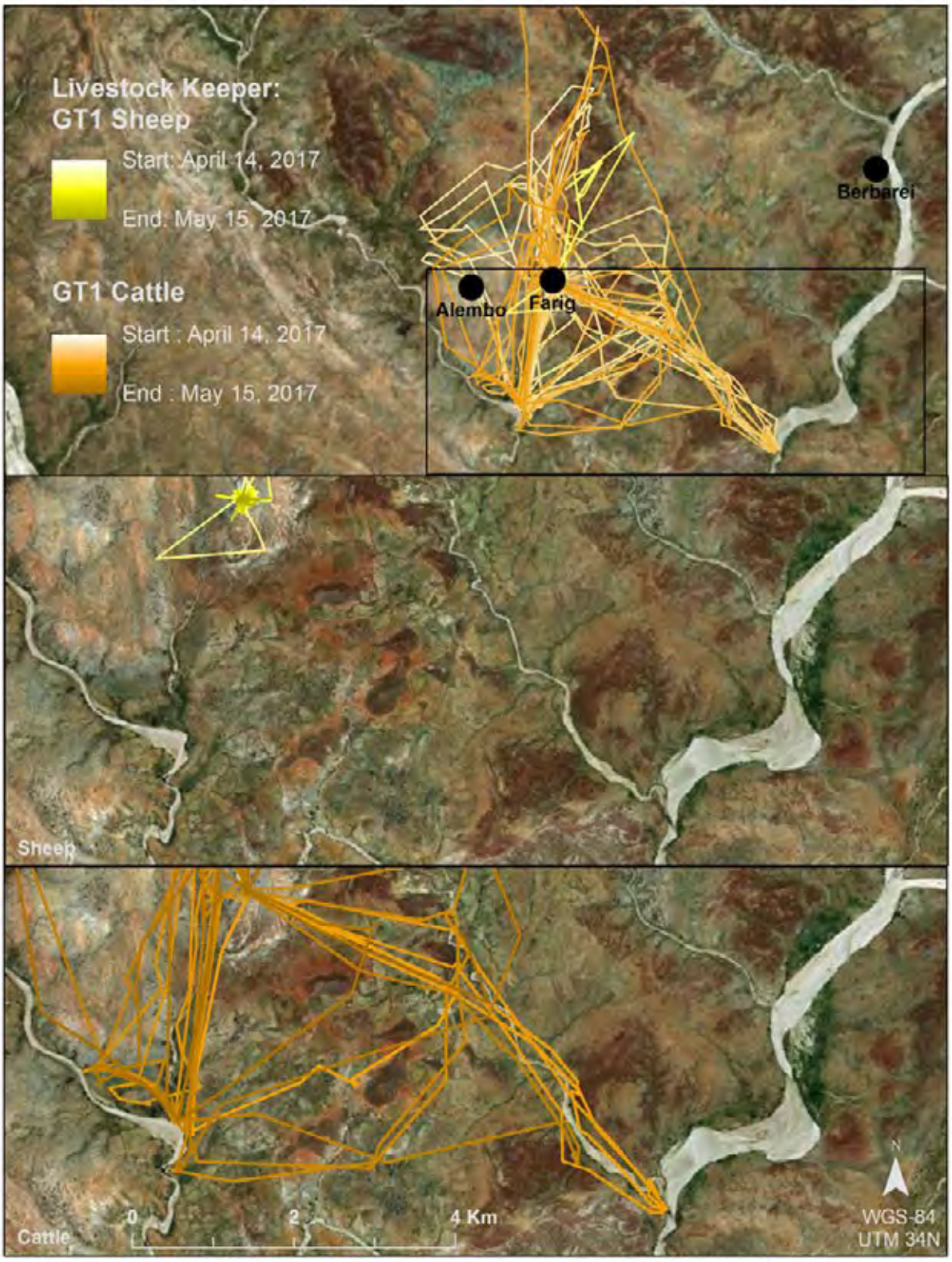


Figure 12. GT1's sheep and cattle herd movement to the watering point along the *wadi* during *seif*.



point (and close to the community location), while his camel herd grazes in more distant areas (up to 40 km from the watering point).

Although *seif* is the hottest season of the year, which means animals are in need of more water, livestock keepers water their animals less frequently in *seif* compared to other seasons. This is mainly due to water scarcity, as they rely on a far smaller number of permanent wells (compared to the numerous water sources available in the rainy season).

To reduce the negative consequences of the harsh climate during *seif*, livestock keepers avoid grazing their animals around midday when temperatures are highest; rather they rest in the shade at midday. To compensate for this loss of daytime grazing, they allow their animals to graze during the night. Because livestock looting occurs during nighttime, they must maintain a close watch throughout the night. Additionally, when they move the herds to the watering points, they move very slowly to avoid harming weak animals that cannot withstand the thirst.

In general, during *seif* cattle and sheep are watered every two to three days and camels every fifteen days. Figure 12 depicts the frequency of movement to water sources of sheep herd owned by GT1 during *seif*.

The livestock must remain within a comfortable distance to the permanent water source, which creates a perimeter around the water point within which pasture resources are diminished from grazing. The pasture that is available within this area is increasingly dried out and of poor quality. Beyond this perimeter, there are likely better pastures, but they are beyond the practical reach of herds in terms of how far they can walk without watering.

At this time of year, pasture and fodder quality and quantity are at their worst. They are also distributed in a fragmented manner, which affect the herds' mobility. These two challenges are interconnected and must be addressed together, as both are needed to sustain the herd.

To make the best use of the heterogeneous rangeland, livestock keepers frequently change the grazing location and continuously look for a new place to graze (Figure 13). This strategy was mainly applied by livestock keepers who spent *seif* in distant grazing lands where there is no major restriction of movement, except for the need to keep within a safe distance of water sources.

Many livestock keepers in the close grazing land move to distant grazing land to avoid competition over limited fodder with other herds. Those keeping their herds in close grazing land all year normally own small herds like KB2 does. He keeps the cattle herd in the vicinity of his village and inside the village overnight. He supplements the diet of the herd with hay stored in the *tabana* (hay storage facility) (see Figure 14).

Figure 13. Features of the rangeland during *seif* in an area on the way to Kulbus.

Figure 14. Photos show (left photo) a group of livestock keepers on their way back from collecting hay and (right photo) the way they store it (known as *tabana*). Photos taken on April 28, 2017 (during *seif*).

5.3.2 Movement in rushash

Although *rushash* is a short transition period from *seif* to *kharif*, it is a very important season for livestock keepers. *Rushash* is when the first showers fall just before the start of the real rainy season. Rainfall is light with a patchy distribution, sometimes described as sprinkles. Surface water begins to collect in rainwater pools in depressions, but the newly emerged greening-up of the fresh vegetation is still light and sparse. In general, livestock movement is relatively free during this season and not tied to water sources along valleys. For example, the GPS records show that the last dates that GT1 from Telehaya sent his sheep and cattle herds to the permanent watering point were May 18 and May 20, respectively, just when *rushash* began. The last date KB1 (from Kulbus in the north) sent his sheep herd to the watering point was May 28.

Livestock keepers race to let their animals graze on the limited new pasture. The higher spatio-temporal variability of the vegetation during *rushash* (Figure 5) requires rapid herd mobility. Some pastoralists move southwards to capture the early rains, while others just roam around and search for locations that were lucky enough to receive the first showers. GT3 is a clear example of moving south to capture the early rains of *rushash* as shown in Figure 15. KB3's herds are an example of staying around the home place and scouting for nearby areas where the new grasses emerged (Figure 16).

The main risk that livestock keepers face during this season is long gaps between rainfall showers. These gaps particularly affect those who advance too quickly away from the permanent water sources, because long gaps between showers put their animals under harsh conditions. Such a gap may force the herds to return to areas with permanent water or to try to access alternative water sources. The second threat to livestock is the increase in looting during *rushash*. Looters take advantage of this time when livestock keepers are scattered and away from home, which means they cannot organize a *fazaa* to recover stolen animals. A third risk is that livestock are generally in a weak condition at the end of *seif*, so as *rushash* starts and the temperature drops, livestock weakened by poor nutrition may be more susceptible to infections.

5.3.3 Movement in kharif

During *kharif*, the quality and quantity of water and pasture are excellent. However, herd movement is restricted with the progression of the rainy season in areas that are cultivated. Flooding of the *wadi* is the only natural factor that can restrict herd movement during the heavy rainy season.

In Telehaya, livestock keepers tend to send herds away from the farming zone during *kharif*. They do so to avoid damaging field crops and to enable their herds to take advantage of fresh, good-quality pasture in the northern rangelands around the area

Figure 15. During *rushash*, GT's sheep herd's southerly movement to capture the first rains.

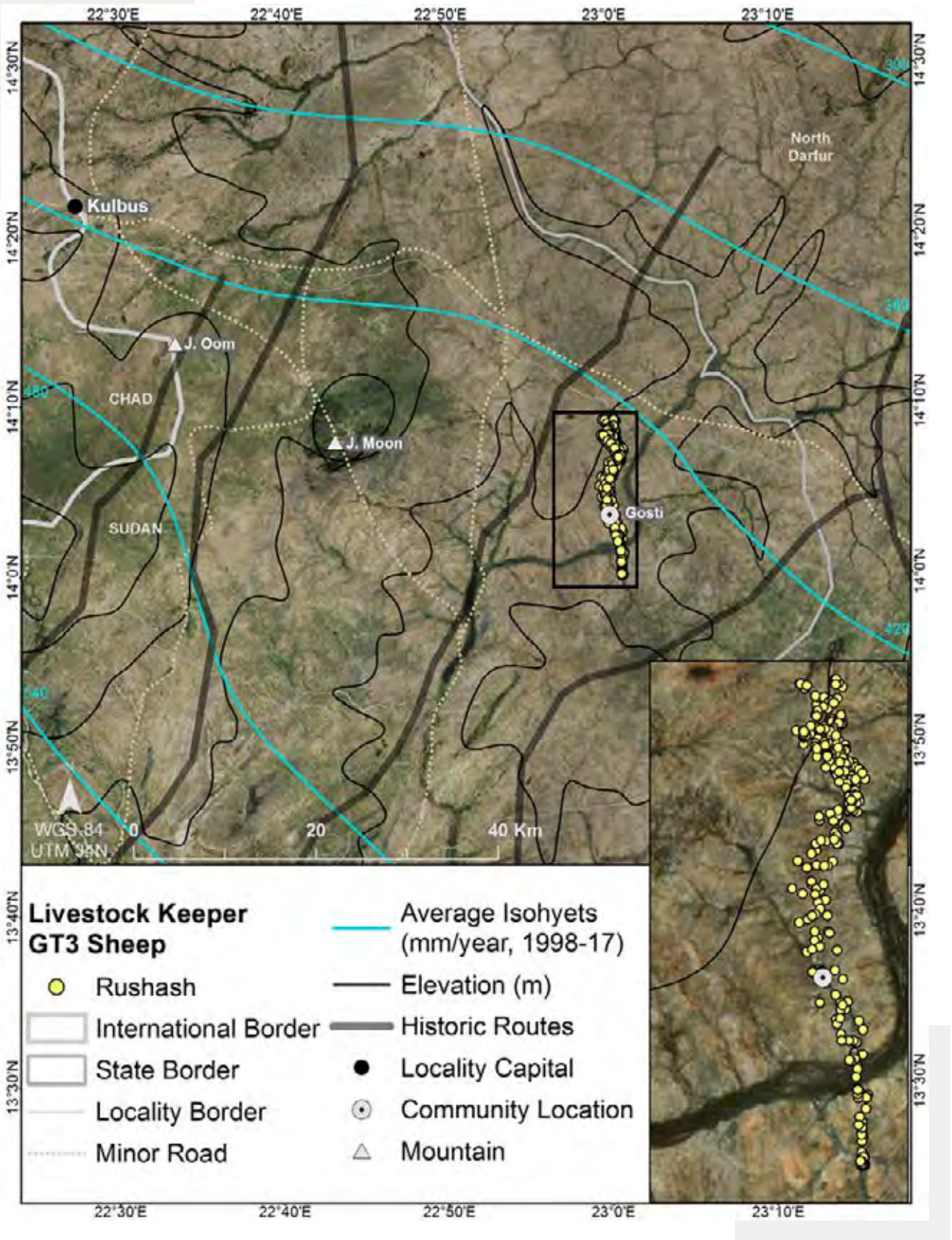
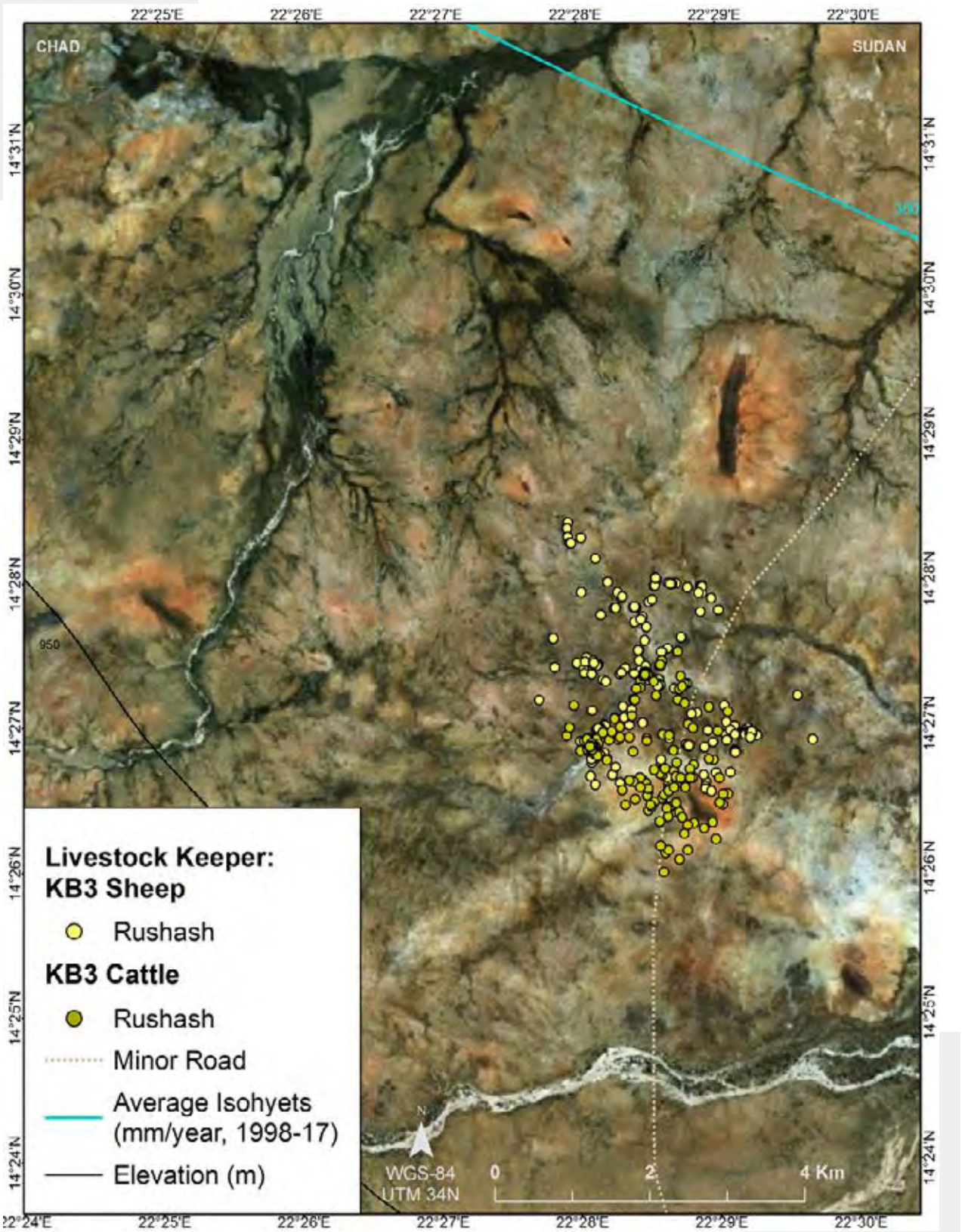


Figure 16. KB3 sheep and cattle herd movement during *rushash* around BIr Taweel.



of Wadi Aradeib. This area is uninhabited, hilly land not suitable for farming. Those who keep their herds around their homes take them to fallow areas or land not suitable for farming to avoid conflicts with local farmers over crop damage. Figure 17 shows that GT1's cattle herd started to move on the northward journey on July 26, while he kept his sheep herd around his home. Figure 19 shows the features of the land where his sheep herd stays during *kharif* to be away from crop fields.

Figure 17. During *kharif*, GT1 sends his cattle herd to the north while he keeps his sheep herd around his home.

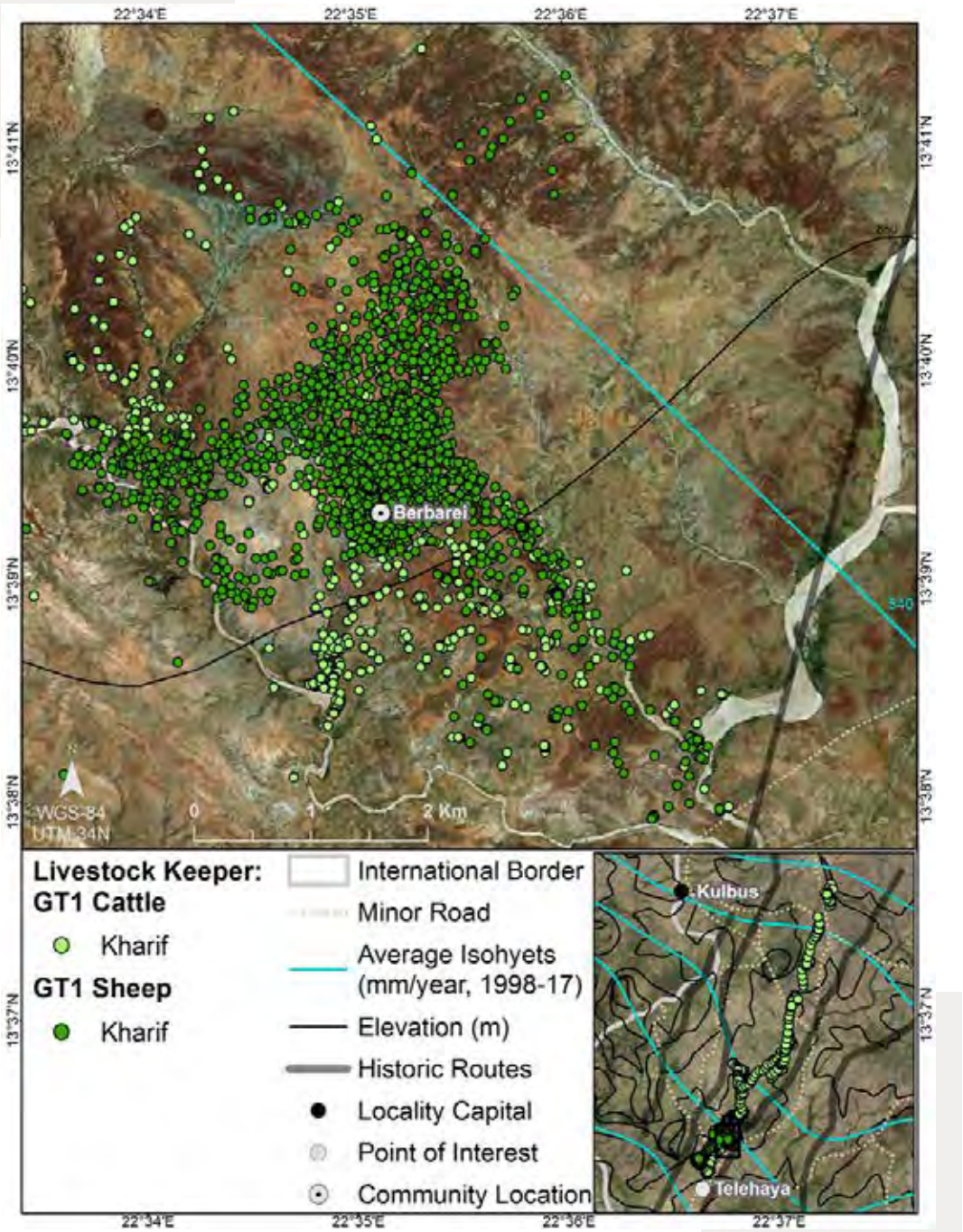


Figure 18. During *kharif*, GT3's camels move farther north compared to his sheep herds.

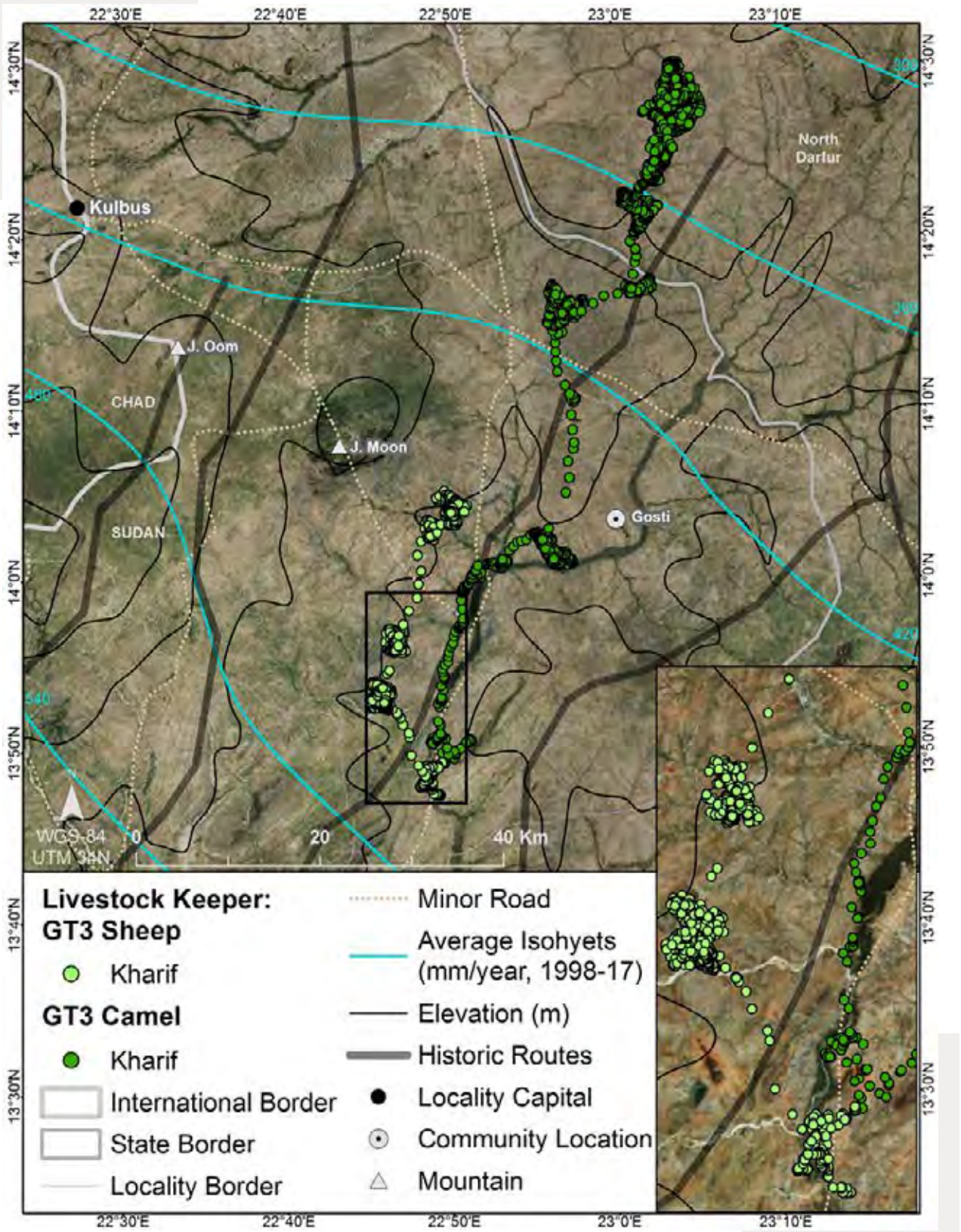


Figure 19. Photo shows the general feature of the land where GT1 put his sheep herd during *kharif* to be away from the crop fields (August 2017).

In contrast, Kulbus livestock keepers tend to bring their herds to their home area during *kharif*. However, as the crop matures they may take their herds out of the area. If they keep the herd in the area, children will watch them closely during the day, and they will tether some of the animals during the night. They explained that tethering some of the older mothers and grandmothers who normally guide the herd is sufficient to keep the rest of the herd in place. Figure 20 shows the cattle herd owned by KG4 staying around his village during the whole of *kharif*. Figure 21 shows that on July 27 KB4's sheep herd was brought to stay near the village.

The livestock keepers reported that clashes over crop damage due to animal trespassing have been less frequent in recent years. As mentioned earlier in the report (Section 3), communities are trying to return to self-sufficiency after the crises. Therefore, they are keen to stay away from accidents that may delay their path to recovery. They have developed many mechanisms and adaptations to avoid problems with each other, which are supported by the fact that communities in Telehaya and Kulbus are engaged in both farming and livestock raising.

Figure 20. KG4's cattle herd spends the entire *kharif* season around his village.

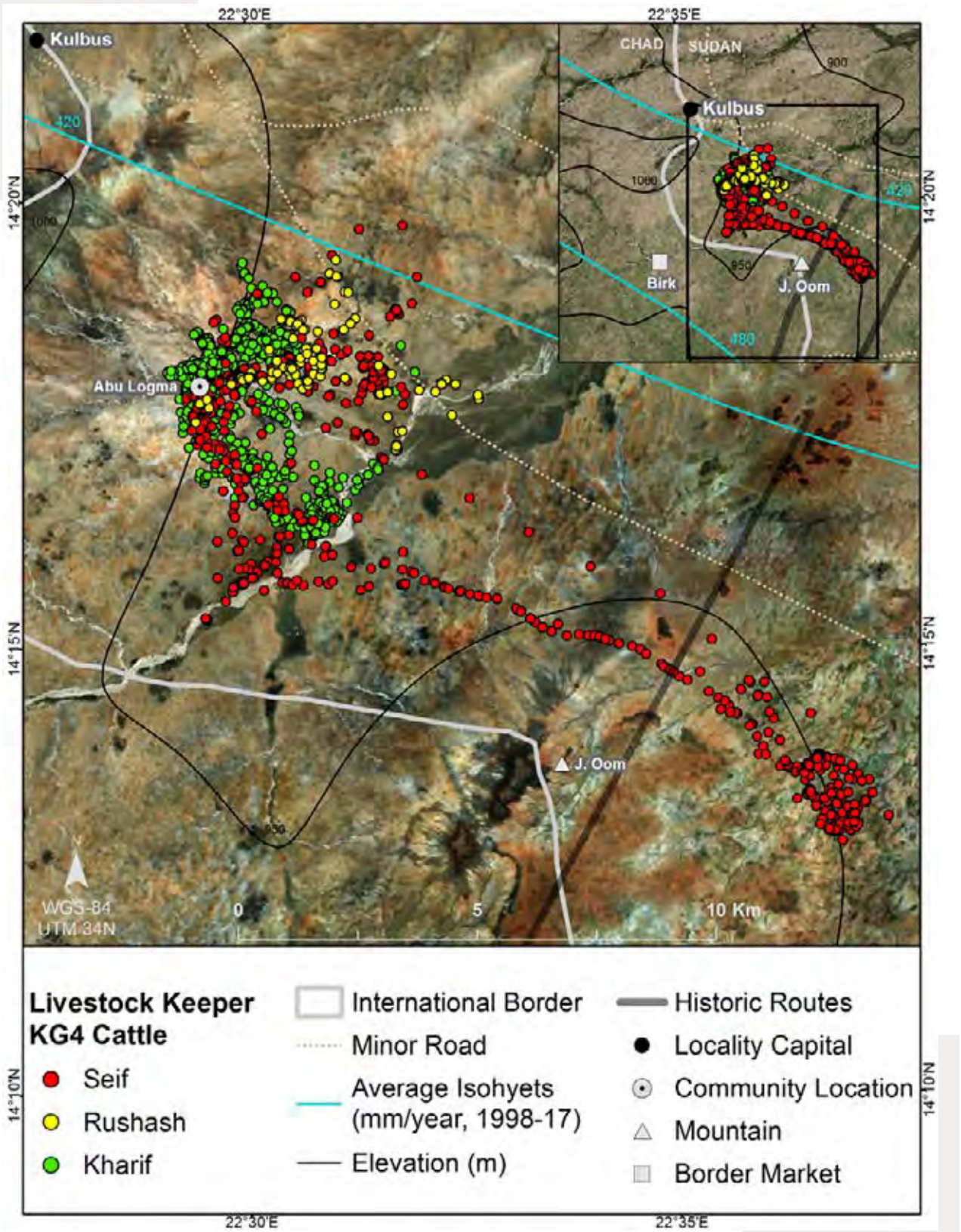
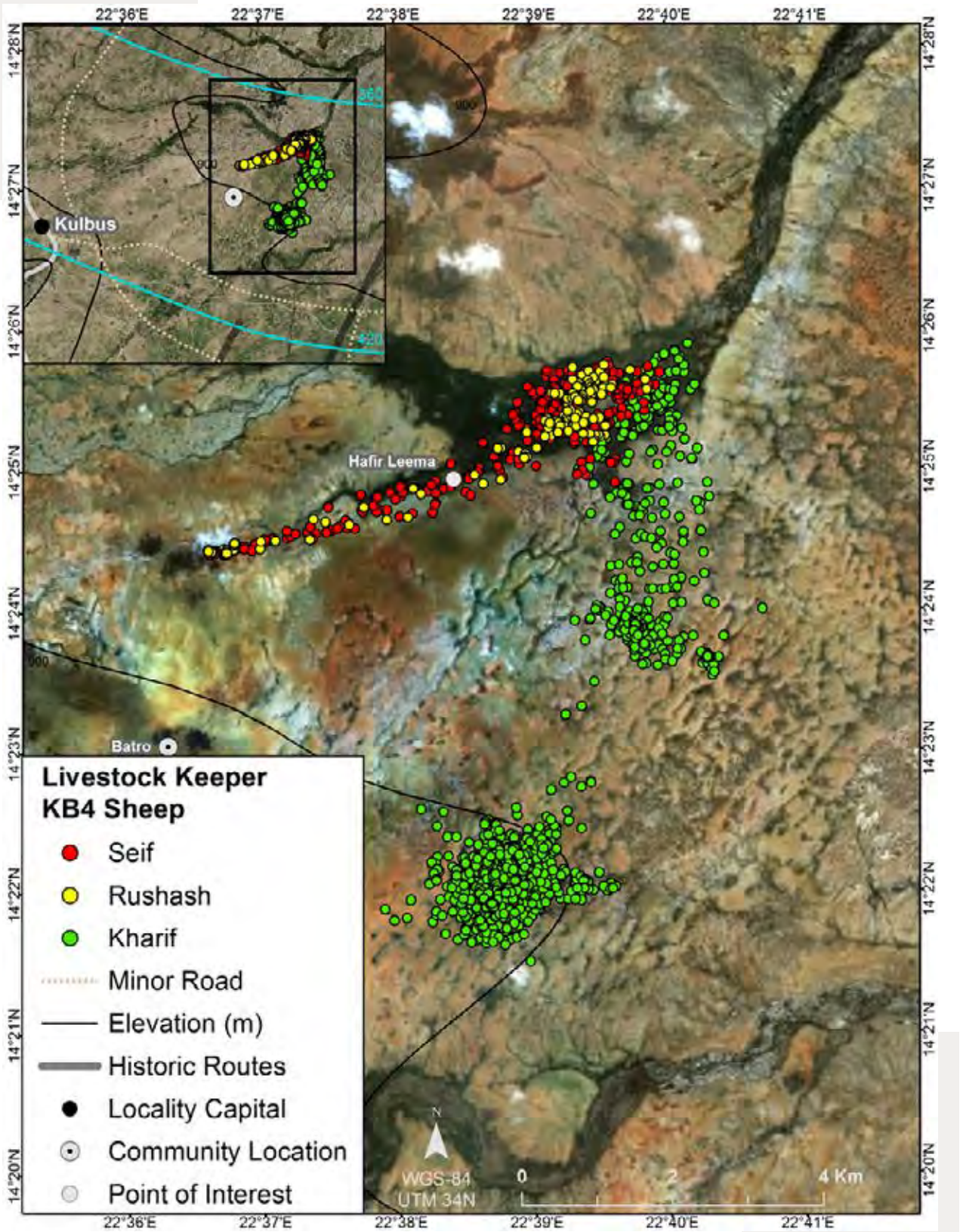


Figure 21. KB4 sheep herd was brought on July 27 to spend the rest of *kharif* around the village.



6. Synthesis: The resilience of livestock production systems in West Darfur, Sudan and their response to crises and climate extremes

This report provides an empirical record of pastoralist mobility and demonstrates its potential. This section highlights some of the key findings and lessons learned from the livestock keepers regarding the management and adaptation of their herding systems. We also present some provisional recommendations, which are intended to serve as the basis for discussion with key stakeholders from the local level upwards. Taking forward such recommendations depends on building a shared understanding and consensus regarding the problems facing livestock systems and producers, and their solutions.

6.1 Understanding climate variability in the Darfur context

Donors, programs, and policy makers are focusing increasing attention on climate change adaptation, as the BRACED program demonstrates by spending £140 million over three years across 13 countries. To properly understand the implications of climate change in the context of the Sudan, one must first appreciate the characteristics of extreme climate variability in drylands. Climate variability is frequently described as "unpredictability;" however, this description is not strictly accurate. There are patterns to this variability, which need to be understood if we are to understand how local producers and production systems manage this variability.

The analysis of precipitation data from 1998 to 2017 highlights five dimensions or aspects of rainfall variability:

- *The start date of the rains,* which starts first in the south and progresses northwards, meaning that planting starts earlier farther south, and fresh grass is first available in the south;
- *The south-north rainfall gradient*, whereby the average annual rainfall increases from south to north, from about 600 mm per annum in El Geneina Locality to about 300 mm per annum in Kulbus Locality, which is around 110 km north of El Geneina (see map in Figure 1);
- *Within-season spatial variability*: within a locale, some areas or even farms may receive rains while others do not;
- *Within-season temporal variability*: within a rainy season, there may be longer, drier periods or rainfall gaps in some areas compared to others, and these may contradict the expected rainfall gradient;
- *Seasonal variability*, with varying total rainfall (and seasonal patterns) between years. These patterns are likely to differ by location, i.e., a good year in one locality may occur at the same time as a bad year in another (Figures 2 and 3).

Given such extreme variability, it is difficult to ascertain the impact of climate change on precipitation, partly because insufficient data are available to examine long-term trends. There are

reports from local communities of a changing climate, particularly in relation to increased episodes of flash floods, increased temperatures during the hot dry season, and, sometimes, strong winds that have a drying affect.

The variability in rainfall influences the distribution and availability of water, pasture, and fodder, which are essential resources for livestock production. Water, fodder, and pasture availability are further influenced by geology, topography, and soil systems. These multiple dimensions of variability and unpredictability are typical of a non-equilibrium environment. The institutional context is similarly complex, with a plurality of customary and legislative systems that control access to land and resources on that land.

These lengthy explanations are necessary, as the thinking of many international and national actors remains stuck in an equilibrium paradigm, and education systems and much of the policy environment is rooted in outdated temperate models of production. As part of the project research uptake, we have used the figures and maps produced in this study to draw out and explain climate variability, with the aim of promoting understanding and making the information more accessible to a wide range of stakeholders, from the producers to the highest-level policy makers.

Recommendations:

- These stakeholder uptake approaches need to be further developed and extended to other regions and contexts and need to be concretely embedded within a multi-sectoral policy context, education, and technical programs.
- Remote sensing data on rainfall and vegetation are freely available and can be used to monitor and mitigate climatic hazards within the region.

6.2 Livestock keeper strategies for managing climate variability: Mobility is of paramount importance

Tracking the movements of livestock herds provides a unique opportunity to capture in real time the seasonal cycle of livestock production and the strategies employed by livestock keepers for managing variability in water, pasture, and fodder.

The predominant and most important strategy for managing variability in rainfall and vegetation is herd mobility, which currently takes different forms, including: long-distance mobility (20 km and above), short-distance mobility (6 to < 20 km), and sedentary (5 km or less from the homestead). The more mobile herds use the following strategies to enhance their productivity:

- With the approaching rains during *rushash* (generally occurring two weeks earlier in El Geneina than in Kulbus), herds race towards the areas receiving the first rains, which sometimes means a dash southwards to benefit earlier from the first rains and first flush of new pasture after the dearth of the long hot dry season. With *rushash*, livestock herds no longer have to be watered at the permanent wells.
- During *kharif*, the northwards trek of the herd takes advantage of the seasonal greening up that affords fresh, more nutritious growth, and of more spacious and cleaner (uncontaminated) rangelands (in contrast to denser farming zones farther south). This northward trek also enables the herds to avoid more difficult conditions associated with heavy rainfall, including pests and mud.
- *Seif* is the toughest time for livestock herds, since they must stay within reach of the permanent deep wells for watering. Frequency of watering varies according to species. Camels are watered less and are therefore able to move to more-distant grazing areas before returning.

It is evident from our study that livestock keepers from both communities (Telehaya and Kulbus) currently practice a more restricted pattern of mobility. This restricted mobility is principally due to risk from bandits and armed groups in the more remote rangelands. Other factors include shortage of water farther north and sometimes blocked corridors. Consequently, distances travelled by camel herds from south to north are shrinking, reaching only as far as Wadi Aradeib in North Darfur today.

Livestock keepers in both Kulbus communities (Bir Taweel and Goshosh) use a short-distance migration that involves circulatory movements to benefit from the pasture within the close grazing zone (up to 19 km radius from the homestead or settlement). In Kulbus, one of the main factors that shapes this general pattern is the availability and distribution of watering sources. Also, this closer proximity of livestock herds to human residences reflects the lifestyle and traditions of long-established settled communities, ones that practice agriculture as their primary livelihood strategy while also keeping smaller sheep and cattle herds. This proximity of herds also allows the Kulbus livestock keepers to divide their household labor between farming and herding activities more flexibly.

In contrast, the Telehaya livestock keepers, whose traditional identity is as nomads, maintain livestock as their primary livelihood strategy, complemented by farming and increasingly a range of other market-based activities given their proximity to El Geneina Town.

The Telehaya livestock keepers whose herds are not big enough to justify the expense of herding long distances combine several herds owned by different households to form one mobile herding unit.

These changes in livestock mobility, in particular the shrinking of the long-distance mobility and increasing importance of the circulatory movements within the short-distance mobility, raise questions about the medium- to long-term sustainability of livestock production and the balance between production systems. Ours is not a representative sample; hence, we cannot estimate the proportion of the total livestock population that is managed under these different regimes. The proportional distribution of livestock between regimes is of relevance to government policy concerned with protecting and promoting productivity and managing resources in a sustainable manner. A re-analysis of the 2007 household livestock ownership data in the national census might shed some light on livestock numbers and distribution. However, there is no substitute for a livestock census, which, given the importance of this sector and changes that have been mapped in this study and others, is needed more now by policy makers than ever before.

Recommendations to national and international policy makers:

- Joint stakeholder review at state and locality level of the practical constraints on livestock mobility and how it can be further supported, including the following specific questions:
  - How can mobility be promoted, from the close zone to the distant zone?
  - What are strategies to develop water resources that balance the water source distribution and output with the available grazing, so as to promote environmental sustainability?
- The West Darfur region supports a range of livestock production and mobility systems, which make a significant contribution to the economy. A livestock census is needed to inform national- and state-level policies and programs; from a macro perspective in relation to how livestock support the national economy and from a more micro/meso perspective as to how producers manage their herds, sustain their livelihoods, and co-manage natural resources in a peaceful manner.

6.3 Other strategies used by livestock keepers for managing variability

Strategies used by livestock keepers for managing variability can be divided by: herd management strategies; herd size and composition; and diversification of livelihood activities.

6.3.1. Herd management strategies to optimize conditions for livestock

Livestock keepers owning more than one species manage their herds seasonally to adapt to variability by splitting their herds by species. This practice allows them to adapt to each species' needs and capacities and to the climate and ecology. For example, different species of livestock selectively graze different pasture or fodder, have different watering patterns, and move at different speeds. When fast movement is required, it may be more efficient to split the herds and move them separately (for example, when moving through farming zones or as a result of insecurity). Splitting herds requires

extra labor, so is only feasible if there is sufficient labor available.

Seif, or the hot dry season, is the most difficult period of the year. This is due to the diminishing water reserves available only from a small number of permanent water sources, and the declining amount and nutritional quality of pasture in areas that are accessible to herds if they are to stay within reach of the permanent water sources that are often few and overcrowded. Livestock must be watered manually, which is an arduous and time-consuming task. Often the area around permanent water sources is overcrowded and overgrazed. As the dry season progresses, it is increasingly contaminated by waiting livestock. Herders must balance the time between regular watering with the time needed for livestock to reach areas with better pasture. The longer time used to reach better pasture means less frequent watering, which could be harmful for health.

Faced with these difficult conditions during *seif*, another strategy livestock keepers adopt to optimize conditions for their herds is adjusting their daily routines. For example, during *seif* herds graze during the night and rest in the shade during the hottest time of the day. Livestock keepers may also use feed concentrates for particular animals, or those who farm may use their own crop residues.

6.3.2 Shifting species preference

Regarding herd composition and preferences for particular species, the study showed a shift from the traditional species (camels and cattle) to sheep. Among our sample, sheep are currently the most commonly owned species, and they are usually owned together with either camels or cattle. The new preference for sheep is driven by fast breeding, increasing market demand, and because moving camels and cattle herds long distances has become more challenging.

6.3.3 Diversification of livelihood activities and managing household labor needs

Most livestock keepers in our study are increasingly diversifying their livelihoods to include farming, if not already practiced, and new activities such as gold mining, vehicle transport between markets, and migration, including asylum seeking in the West. This livelihood diversification must be balanced with the available household labor and skills. We detected the following continuing and new trends: use of girls for herding; use of hired labor for farming and herding; and combining herds with herds of other livestock keepers to achieve economies of scale in relation to migration. Additionally, the practice of close mobility (rather than long migrations) enables the livestock keeper to better balance household labor needs. For example, in remote areas the herd is managed by mature male members of the household, while in the home zone young boys and girls look after the herd.

When either livestock or farming are adopted as a secondary activity, they play a support role to the primary livelihood. For specialist pastoralists, like the Telehaya community, farming can: serve as a source of income and so reduce the need for livestock sales to generate cash; provide fodder as crop residues; and act as a form of insurance in case of drought by providing fodder for livestock. For specialist farmers, livestock serve as: a source of income (to buy agricultural inputs at the beginning of the rainy season); a form of investment (using post-harvest income to build their herds); and a form of insurance in case of harvest failure.

Recommendations

- Review conditions around permanent water sources. Consider providing shade and reducing pests to improve the health environment. Consider supporting services for herders and livestock, including more efficient and faster systems of watering livestock.
- Review the balance between availability of permanent water sources and availability of pasture. There may be a need to increase the number of water sources, while potentially reducing their output (so as to reduce or limit use and protect pastures). Promote the commercial provision of portable bladders.

6.4 Practices for managing climate shocks and conflict

6.4.1. Managing climate shocks and extremes

The livestock keepers in this study identified *mahal* and floods as the two major climate shocks affecting

them. Specific recent dry years mentioned by livestock keepers included 2004, 2010, 2014, and 2017. Livestock keepers in Telehaya identified the consequences of the 2017 *mahal* as worse compared to previous dry years, because of the competition from the camel herds coming from Chad who compete for the limited water, pasture, and fodder. Camel herds consume larger amounts of pasture and fodder than do cattle and sheep. Informants described that a specific pasture can maintain a sheep herd for three months, or it can be consumed in one month by a camel herd. This confirms one of the findings of a related livelihoods study: when communities face a combination of shocks, such as the drought year of 2017 combined with the vociferous camel herds coming from Chad, the impact is more severe and potentially longer lasting (Young and Ismail, in press).

Coping strategies practiced in dry years include: moving herds more often from place to place in search of better pasture or fodder; cutting branches from trees; shaking off the seeds and pods to feed animals; feeding weak animals with concentrated feeds bought commercially; and destocking the herds.

During the field visits to Goshosh, we observed that a high concentration of livestock around trees was causing overgrazing and degradation of the tree cover around the village (Figure 22). According to key informants, there are severe pressures on the remaining forest in the surrounding area, which will never decrease because there are no alternative grazing resources in dry years.

The 2015 flood affected many livestock keepers from Telehaya and Bir Taweel. The flood occurred in *rushash*, during which time the wadi and surrounding lowlands are the only source of fodder. Also during *rushash*, small pockets of water or pools of water are likely to collect following the first light rains in these areas. KB2 explained that the *wadi* areas, and in particular Wadi Bardi, are the main grazing and watering places for livestock herds in Bir Taweel in *rushash*. Therefore, many animals were present when

Figure 22. Example of damage to trees caused by livestock keepers.

water suddenly filled the *wadi.* He lost 5 heads of cattle and 20 heads of sheep during this flood. KB4 lost 80 heads of sheep.

6.4.2 Impact of conflict and managing insecurity

The wider Darfur conflict that erupted in early 2003 and affected the entire region has brought about significant and long-lasting transformations to livelihoods. The livestock keepers recounted some specific events that affected their households. The most severe conflict period was from 2003 to 2010, during which many Telehaya livestock keepers changed their way of life and livelihood from totally nomadic to settling and becoming partially transhumant. In contrast, during this period many communities in Kulbus were displaced. The Bir Taweel Sheikh described how the village was abandoned due to conflict, and now only around 50% have returned to their houses from internally displaced person (IDP) camps or towns such as Kulbus. Accordingly, the number of livestock diminished, and some households lost all their livestock.

Kulbus livestock keepers' first reaction to security incidents in the area is to take animals to a distant, secure place if the herds are large. If the herds are small, they try to keep them inside the village. KG4 from Goshosh said that he kept his sheep herd in a zariba (enclosure for animals) and fed them hay to avoid insecurity. During this period, GT1 changed his annual movement from a long cycle that reaches areas parallel to Attina in the north to one not farther than Kulbus. He also mentioned that livestock keepers moved in big groups to support each other in case of insecurity incidents, as a high number of livestock raids were reported during this period.

Currently, livestock raiding still continues in Telehaya and has been acknowledged as the main insecurity problem facing livestock keepers in the area. In 2010, GT2 lost 81 heads of camel. Twenty-seven heads of sheep from GT3 were taken by raiders in the *rushash* of 2015. Now he uses guard dogs to watch the animals at night.[15] KG3 told us that in 2016 the corridors that they use to exit the farming zone on the way to Jebel Moon were totally blocked by earlier conflict and had not yet re-opened, so they had to take an alternative long route to reach their destination.

This study has also shown that the motivations for livestock settling, including both push and pull factors, are largely independent of the continuing role and importance of livestock mobility in sustaining the herd. Thus, a process of nomads settling does not necessarily mean reduced mobility and productivity of livestock.

Recommendations

- Policy makers need to be informed that patterns of livestock mobility are changing, as livestock keepers juggle multiple competing factors, including climate, environment, economics, and security. Each of these plays a complex role in herd management and decision-making, and the decisions that herders take ultimately have implications for the local and national economy, and for the sustainability of Sudan's livestock and rainfed farming sector.

15 Our baseline survey showed that communities that identified as nomadic own many more dogs than traditional farming communities, most likely because of the dogs' role in protecting the herds.

7. Conclusions

Among our sample of livestock herds, we found that livestock production systems are wide ranging, including different species, herd sizes, and patterns of mobility. We conclude that livestock mobility is the single most important factor that determines ecological sustainability, optimizes conditions for livestock, and reduces tensions and conflict with farmers. Furthermore, livestock play different roles according to the producers' livelihood strategies and their specializations. This calls for a more strategic and tailored policy and programmatic response depending on the livestock production system, to promote the multiple benefits of livestock mobility while recognizing and addressing the challenges facing owners of smaller livestock herds, especially women.

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Acronyms and abbreviations

BRACED Building Resilience and Adaptation to Climate Extremes and Disasters

BRICS Building Resilience in Chad and Sudan

CWW Concern Worldwide

GPS Global Positioning System

km Kilometer(s)

mm Millimeter(s)

MODIS Moderate Resolution Imaging Spectroradiometer

NDVI Normalized Difference Vegetation Index

SPE Satellite Precipitation Estimates

TMPA Multi-Satellite Precipitation Analysis

TRMM Tropical Rainfall Monitoring Mission

Glossary of Arabic terms

ankoleeb: sweet sorghum

atroon: a type of salt

damin: guarantor

damra: established nomadic settlement usually adjacent to an established village

deret: pre-harvest and harvest period

farig: temporary pastoralist camp

fazaa: mobilization of men of fighting age to recover stolen livestock

galaji (n)/galaja (v)*: livestock trader/ livestock trade

goz: sandy soil

groon: horn

haj: pilgrimage to Mecca

hasad: harvest

jroon: traditional granary

kharif: rainy season

magela: resting the herd in a middle of the day to avoid high temperatures

mahal: dry years

mukhamas: unit of farm size; 1 mukhamas = 1.8 acres or 0.73 hectares

murhal: traditional livestock route or corridor

nafeer: calling on the community for help with specific work

rushash: season in which the rains begin

sababi: broker

seif: hot dry season

serba: nighttime grazing

serha: a livestock management system in which several livestock keepers combine their herds and hire a pastoralist herder to bring the combined herd to the area surrounding the village, such as nearby rangeland, and return the animals to their owners late in the evening

shamam: yellow (musk) melon

shita: cool dry season

tabana: hay storage facility

talaig: the practice of common access of livestock to graze crop residues after the harvest has been taken in

tibish: wild cucumber

wadi: valley that has a seasonal water course

Wali: state governor

zariba: enclosure for animals

*n: noun; v: verb

Annex 1.

Interview for the Outreach Visits

A. Basic Information

1) Herder ID: ..... 2) Date of interview: ..... 3) Name of the place: .....

B. Herd/Livestock Management

1) Relative importance of each herd/species (camel, cattle, sheep and goat) in case the herder owned more than one herd: Rank the species you owned from most important to least important in terms of quick source of income, culturally preferred, source of milk products, drought resistant, ... etc.

Utility or benefit	Most important	Second	Third	Least	Reasons

C. Destocking and restocking of herds

1) What are the reasons/causes (forced and optional) for destocking of each of livestock species you owned?

Species	Reasons

2) What is the suitable season/period of the year for destocking of each species and why?

Species	Reasons

3) What are the reasons/causes for restocking of each of livestock species?

Species	Reasons

4) What is the suitable season/period of the year for restocking of each species and why?

Species	Reasons

D. Livelihood activities (other than animal rearing and farming)

1) Livelihood activities other than livestock rearing and farming by household members

Activity	Family member	Date of starting (ending)	Reasons for practicing the activity	Implications on managing the herd(s) tasks (positive or negative)

E. Consequences of insecurity on livestock ownership and management aspects
Compare the situation before the insecurity

Aspect		Before conflict	Current situation
Livestock ownership (Preferred or dominant species)	sheep		
	cattle		
	camel		
Herding labor	male		
	Female		
	Shared labor		
Water sources	Natural sources		
	Man-made sources		
Access to markets			
Selling livestock products			

Monthly Report Template for State Focal Point

Date of the report:.....

1) Situation of livestock during this month:
General description of the situation of livestock in the state in terms of health, emerging diseases, vaccination campaigns, activities relevant to the project undertaken or supported by the ministry.

Activity	Description

2) Updates on legislations and regulations
General description of laws, acts, forums and meetings of the Agricultural Season Committee, or other related institutions in relation to livestock movement or distribution (such as date of *talaig*) that were issued or activated during this month.

New legislation, committee or activation	Partners involved	Objectives

3) Mobile livestock distribution

General locations/distributions (north, central and north) of mobile livestock (cattle, camel and sheep in the state) in the state during this month and the factors causing the distribution.

Species	Distribution	Factors

4) Factors affecting livestock mobility

General description of events that might affect or challenge livestock mobility in the state such as, lack of pasture, water shortages and insecurity.

Factor or events	Areas or location affected	Impacts or consequences

5) Cross border pastoralism

Movements of livestock and pastoral groups across the border with Chad and Central Republic of Africa including of information about joint committees, meetings and trading.

Border area	Pastoral group	Causes

6) Situation in Geneina and Kulbus Localities

Any emerging issues in El Geneina or Kulbus Localities relevant to livestock mobility

Locality	Emerging issue
Geneina	
Kulbus	

7) Follow up with focal points

Update and follow up with locality focal points and continuation weekly phone call.

Locality	An overview
Geneina	
Kulbus	

Questionnaire for Weekly Phone Call

A. Herder ID: .....
B. Date of calling: .....
C. Name of the place of herd at time of calling:.....
D. Date of arrival: .....
E. Condition of the device and the collar/leather: .....
F. Date of last call.....
G. Livestock health
Since we last spoke, did any of your livestock become sick, or recover from disease?
Yes No

If yes, which disease(s) were they?

Livestock Species	Disease		Health Change	
	List of local disease names	Other names if possible	Became sick	Recovered

H. Rainfall observations
In the places where the herd was staying, if it has rained since we last talked then:
How many days did it rain: .....

I. Water
1) Where did you water your herd?

Type of Water Source (code)	Nearest place name

2) What were conditions at the water points you used?

J. Fodder
Beginning with the most important food source, list the five (if available) most important forage plants, including grasses, trees and shrubs, that your animals have been eating since we last spoke.

Grass or tree name	
Write local name	Other names if any

Anything you would like to add you think is important

Annex 2.

Total number of days (and %) that the recruited livestock herds spent in different grazing zones during the last year (May 2016–April 2017)

Locality	Community	Pastoralist	Species	Home area		Close grazing land		Distance grazing land	
				No. of days	*%*	*No. of days*	*%*	*No. of days*	*%*
El Geneina	Telehaya	GT1	Sheep	166	45	76	21	123	34
			Cattle	166	45	76	21	123	34
		GT2	Camel	0	00	275	77	90	33
		GT3	Sheep	206	56	72	20	87	24
			Camel	0	00	176	48	189	52
		GT4	Cattle	177	49	93	25	95	26
		GT5	Sheep	274	75	91	25	0	00
Kulbus	Bir Taweel	KB1	Sheep	62	17	50	13	253	75
		KB2	Cattle	93	25	272	75	0	00
		KB3	Sheep	44	12	321	88	0	00
			Cattle	44	12	321	88	0	00
		KB4	Sheep	0	00	365	100	0	00
	Goshosh	KG1	Sheep	98	27	267	73	0	00
			Cattle	98	27	267	73	0	00
		KG2	Cattle	291	80	74	20	0	00
		KG3	Sheep	0	00	0	00	365	100
		KG4	Cattle	365		0	00	0	00
			Overall average	**122.6**	**29.4**	**164.5**	**45.2**	**77.9**	**22.2**
			%	**33.6**	**8.0**	**45.1**	**12.4**	**21.4**	**6.1**

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