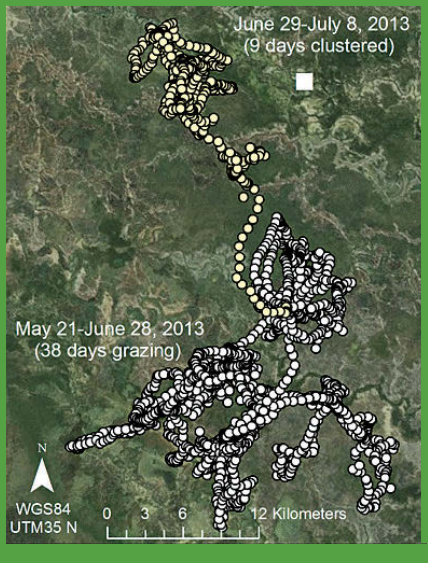
AUGUST 2016

Feinstein International Center

Strengthening the humanity and dignity of people in crisis through knowledge and practice



Risk, Resilience, and Pastoralist Mobility

Helen Young, Roy Behnke, Hussein Sulieman, Sarah Robinson, with Abdelhafiz Mohamed

MINISTRY OF LIVESTOCK, FISHERIES AND RANGELANDS

Al Massar

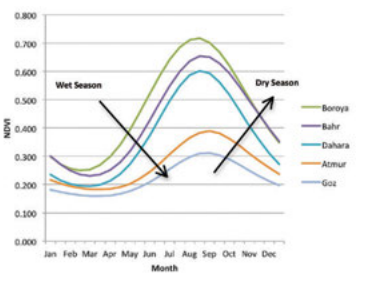
Tufts UNIVERSITY | GERALD J. AND DOROTHY R. Friedman School of Nutrition Science and Policy

Photos: Hussein Sulieman

Report authors: Helen Young, Roy Behnke, Hussein Sulieman, Sarah Robinson, with Abdelhafiz Mohamed

Editing: Carol Kerven, Liz Vincent and Anne Radday
Photos: Hussein Sulieman
Report layout: Bridget Snow Design
Maps: Madeline Wrable, Hussein Sulieman

Feinstein International Center
Tufts University
114 Curtis Street
Somerville, MA 02144
USA
tel: +1 617.627.3423
fax: +1 617.627.3428
fic.tufts.edu


0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
NDVI
Wet Season
Dry Season
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
Boroya
Bahr
Dahara
Atmur
Goz

ACKNOWLEDGEMENTS

This study was funded by the Foreign and Commonwealth Office of the United Kingdom, and UK aid from the Department for International Development.

At the heart of this work has been a close collaboration between partners, including the Federal- and State-level Ministry of Animal Resources, especially the Director General of Planning and Livestock Economics, Dr. Ammar El Shikh Idris Omer in Khartoum. In East Darfur, special thanks are due to Dr. Hamid Mohammed Abdelnabi Adam, Director General, State MLFR and Madam Syda Ahmed Omer Mohammed, Veterinarian (MLFR, Ed Daein).

The national non-governmental organization (NGO) Al Massar Organization for the Development of Nomads has been a partner since the start of this work, and their staff in Ed Daein and Khartoum deserve special thanks, including Executive Director Osman Hussein and Head of Office for Ed Daein, Hamid Ahmed Mohamed. National NGO SOS Sahel Sudan has played an important role, and thanks are due to Director Salih Abdal Mageed El Douma for his continuing support.

In East Darfur, for introductions to the pastoralist communities and local tribal leaders, specialist knowledge, and most excellent participation in the Khartoum analysis workshop, thank you to the tribal leadership and their families, especially Omda Aamir Mohamed Aamir in Abu Matariq, East Darfur.

For support with data analysis and desk studies, thanks are due to Merry Fitzpatrick, Emily Cole, and George Blackburn. Thanks also to Jason Harris for helping fix one particularly troublesome device. We especially want to thank Madeline Wrable for her most excellent maps.

For cleaning the data and translation of technical terms thanks are due to Janet Aamir and Samira Mohammed Ahmed.

Finally, our sincere and most grateful thanks to the pastoralists who willingly participated in the study and joined us in various meetings and workshops.

Contents

Executive summary **8**

Introduction **15**

Methods **17**
Partners and research personnel 17
The GPS tagging devices and livestock collars 17
Data and analysis 18
Strengths and limitations 19

Part 1. The seasonal imperative: Environmental drivers of livestock mobility **21**
The study area—Why move? 21
Rainfall events and nomadic response 24
Forage—quantity versus quality 33
Plant growth and forage quality 39
Dry season grazing and water availability 41
Changing patterns of migration: Anticipating problems and dealing with the unexpected 46
Discussion and conclusions: Heterogeneity, risk, and resilience 48

Part 2. Pastoralist livelihoods: Social and economic dimensions **51**
Introduction 51
Economics of pastoralist livestock marketing and trade strategies 51
Diversification of pastoralist livelihoods, including farming and other economic activities 51
Social division of roles and responsibilities 53
Specialist knowledge of pastoralists 53
Specialist knowledge of Baggara women 55
Conclusions 56

Part 3. Pastoralism: Role of local governance, relationships, and integration with others **59**
Introduction 59
Role of local governance in regulating pastoralist mobility and coexistence with other groups 59
Tensions as pastoralists move through farming areas 60
South Sudan: Relations between the Southern Rizeigat and the Dinka Malual 62
Inter-tribal conflicts: What link, if any, to pastoralist mobility? 65
Conclusions 65

Conclusions and recommendations **67**
Mobility as a strategy to turn temporary deficiencies to advantage 67
Water and pasture: Two vital and related issues 68
Pastoralist livestock marketing strategies—aim of investing in the herd 68
Farming and herding: Integrated by form, function, and necessity 69
Governance of pastoralist mobility: What works? What remains to be done? 70

continued on next page

References **72**

Acronyms **76**

Glossary **77**

Annexes **79**

TABLES

Table 1. Natural features of the pastoral zones along the central livestock corridor of East Darfur 23
Table 2: Environmental advantages and disadvantages of the different pastoral zones for livestock production 24
Table 3. Mean green-up and die-back dates: 2001–2014 40
Table 4. Mean daily distance of Pastoralists 1, 2, and 4 Cattle 48
Table 5. Landscape utilization in ranching and pastoral systems 50
Table 6. Three main plants consumed by cattle in East Darfur and by camels and sheep in North Kordofan 54
Table 7. Three main trees and shrubs used by cattle, camels, and sheep 55
Table 8. Three main trees and shrubs eaten by cattle by season 55
Table 9. Examples of trees, shrubs, and other natural products collected or harvested by Baggara women 57

FIGURES

Figure 1. Map of East Darfur showing the central livestock corridor and the movements of four pastoralist cattle herds from May to September 2013. 11
Figure 2. Map of East Darfur showing the central livestock corridor (Almurhal Alwastani) and the movements of six pastoralist herds from February to May 2015 12
Figure 3. Map of East Darfur showing the long-term average rainfall isohyets (2000 to 2016) and the average annual rainfall for 2013 and 2015. 13
Figure 4. Map of East Darfur showing the long-term average NDVI isohyets (2000 to 2016) and the average annual NDVI for 2013 and 2015 14
Figure 5a. Pastoral zones in eastern Darfur. 22
Figure 5b. Schematic migratory cycle for cattle pastoralists in eastern Darfur. 22
Figure 6. The cumulative southward movement of Pastoralist 2 Cattle (ED2C-15) from February to May 2015 and the daily precipitation at the starting location of migration and at the destination location 25
Figure 7. Migration south at the end of the dry season by Pastoralist 2 Cattle, 2015 26
Figure 8. Panel representing eastern Darfur showing total rainfall between May 3 and May 17, 2015 and daily southward movement of Pastoralist 2 Cattle from February 8 to May 29, 2015 27
Figure 9. The amount and distribution of rainfall by week from May 24 to September 27, 2013 28
Figure 10a. The daily movement of Pastoralist 1 Cattle, 2013 29
Figure 10b. The daily movement of Pastoralist 4 Cattle, 2013 30

continued on next page

Figure 10c. Northward movement of Pastoralist 1 Cattle from May 28 to August 28, 2013 and the total weekly rainfall beginning August 9, 2013..... 31
Figure 10d. Northward movement of Pastoralist 4 Cattle from June 8 to August 10, 2013 and total weekly rainfall beginning August 9, 2013. 31
Figure 11. The cumulative northward movement in 2013 of Pastoralist 1 Cattle and the daily precipitation at the start and destination locations..... 32
Figure 12. The cumulative northward movement in 2013 of Pastoralist 4 Cattle and the daily precipitation at the start and destination locations..... 32
Figure 13. Seasonal fluctuations in monthly rainfall in East Darfur, 2013 to August 2015..... 34
Figure 14. Seasonal fluctuations in NDVI and rainfall in eastern Darfur for 2013..... 34
Figure 15. Seasonal fluctuations in mean NDVI across the five different pastoral zones in eastern Darfur, 2001–2014..... 35
Figure 16a. Long-term mean biweekly NDVI for each of the five pastoral zones in eastern Darfur from 2001 to 2014. 35
Figure 16b. Long-term mean monthly rainfall for five pastoral zones, 1979 to 2014. 36
Figure 17. Cumulative northward movement of Pastoralist 4 Cattle and annual and biweekly NDVI for locations occupied by cattle at time of actual use..... 37
Figure 18. Cumulative southward movement of Pastoralist 2 Cattle in 2015, mean annual NDVI for locations occupied by cattle, and biweekly NDVI for these locations at time of use. 38
Figure 19. Cumulative southward movement of Pastoralist 2 Cattle in 2015 and annual NDVI curves at starting location on February 8 and destination location on May 28, 2015..... 38
Figure 20. Rate and direction of change in NDVI, by pastoral zone..... 39
Figure 21. Dry season grazing patterns of Pastoralist 5 Sheep along the Bahr el Arab River, 2015..... 42
Figure 22. Seasonal use of different water sources by cattle pastoralists in East Darfur from March to November 2013. 43
Figure 23. Water quality of different water sources by month as scored by East Darfur pastoralists, 2013. 43
Figure 24. Grazing cattle near dahal in the vicinity of Um Sagei in the Bahr area..... 44
Figure 25. Migration north of Pastoralist 2 Cattle from the end of the dry season to the establishment of the rains in 2013. 47
Figure 26. Grasses and herbs consumed by cattle in East Darfur 54
Figure 27. Tribal meeting in East Darfur (February 2015). 64

ANNEXES

Annex 1. Characteristics of the two GPS tagging devices 79
Annex 2. List of grasses, shrubs, and trees identified as fodder sources by pastoralists in the 2013 longitudinal study..... 80
Annex 3. Maps of livestock mobility in 2015..... 83

Executive summary

Based on new evidence from Darfur, this report presents a scientific account of the environmental principles of pastoralist livestock mobility, combined with a review of other key influences on livestock movements throughout the year. Our goal is to provide policy makers and other stakeholders with an objective account of what mobile pastoralists in Darfur can achieve, how they do it, and what they might need to do it better. The intention is to raise awareness and understanding, so as to inform programs and ways of working at all levels, which should also help correct misperceptions and begin to shift negative attitudes towards pastoralism more generally.

The evidence reported here reflects two time periods of monitoring pastoralist herds in eastern Darfur, during the rainy season in 2013 (Figure 1) and during the dry season in 2015 (Figure 2). The monitoring component combines remote sensing data—rainfall and Normalized Difference Vegetation Index[1] (NDVI)—with GPS livestock monitoring results (collected by satellite global positioning tracking collars on livestock). The study adopted weekly questionnaires and qualitative approaches to investigate other influences on mobility, including livestock marketing and trade strategies, livelihood diversification, relations with other land users in eastern Darfur and in South Sudan, unanticipated inter-tribal conflict, and local governance linked with access to and management of natural resources (specifically water and pasture).

The study findings and analysis produced five broad conclusions, each of which led to specific recommendations that are presented below.

Mobility as a strategy to turn temporary deficiencies to advantage

At their furthest extent, the migratory routes examined in this report traverse 400 km or more along a north-south transect in a single year. The pastoralists who travel these routes cross what they recognize to be six distinct pastoralist grazing zones. In the course of a year, each of these environments provides conditions and resources that are favorable for livestock production, but at other times of the year pose problems. Seasonal migration in East Darfur is all about using an area when conditions are favorable, and avoiding it when conditions deteriorate. Pastoralists seize opportunities and evade hazards. Generally, the southern parts of East Darfur are too wet for livestock in the rains, exactly when northern pastures are wet enough, while conversely, northern areas are lacking in forage and water in the dry season, when these resources are available further south. The overall pattern of movement is therefore an annual oscillation, north in the wet season and south in the dry season. Manipulating of space and time by pastoralists—where they are and when they are not there—is the essence of mobile strategies for exploiting environmental heterogeneity.

The husbandry techniques that pastoralists use to pursue this strategy are not immediately obvious, widely understood, or respected. This report relies heavily on remote sensing data to document pastoralist behavior in relation to some of the biophysical factors that are important for livestock production in East Darfur. The analysis of the data gained through the study has led to the following nine recommendations.

Recommendation: Understanding pastoralist mobility

1. Develop a strategic program to increase knowledge and awareness among officials and the public at large of the role and importance of pastoralism in Sudan. This can be achieved through a knowledge transfer and skills development program, building on earlier successes under the UNEP Sudan Integrated Environment Programme (SIEP).

[1] In the Normalized Difference Vegetation Index (NDVI), a zero means no vegetation, and close to +1 (0.8–0.9) indicates the highest possible density of green leaves.

Water and pasture: Two vital and related issues

The number-one issue and priority development need for pastoralists in East Darfur is the availability and quality of water during the dry season. Dry season access to pasture for livestock is determined by access to water, so the two facets, pasture and water, should always be considered together. Currently, development planning of water resources prioritizes the more permanently populated (farming) areas of East Darfur, while ignoring the acute dry season needs of pastoralists from the wider region when they are concentrated in the Bahr River valley.

Recommendation: Planning and coordination of basic service delivery

2. Service delivery must take account of the specific dry season demands, linked with increased migration of pastoralist herds to the Bahr region, and the twin needs of watering livestock and having access to adequate pasture.

Pastoralist livestock marketing strategies—aim of investing in the herd

There is evidence of an explicit pastoralist investment strategy. Pastoralists with large herds are able to purchase animals that are thin but healthy at the time of year when pastoralists with smaller herds are under stress in the dry season, prices are low, and buyers know they can fatten the thin livestock by taking them further south to the Boroya. Conversely, they sell their animals when the animals are in peak condition, as they move north through the larger markets frequented by Omdurman traders, where the animals fetch a higher price. Only producers with sufficiently large herds and expertise can play the market in this way. Pastoralists also have an interest in expanding their herds to include sheep, which is a relatively new trend. We need to better understand the implications of these trends for resource use (water, pasture, and fodder) and the region's economy.

Recommendation: Livestock marketing

3. Conduct studies of the environmental and economic implications of expanding pastoralist production to include sheep herds at these latitudes and implications for cattle herds (if any).

Farming and herding: integrated by form, function, and necessity

Farming and raising livestock underpin household and regional food security and form the basis of the local economy. These two livelihood systems often compete for resources, creating tensions within the farming zone between pastoralists and farmers. Our data show that when herds move through the heavily farmed zone, they are in rapid transit and not grazing extensively. Therefore, relatively little potentially arable land is needed for these narrow transit corridors. However, the payoff from maintaining livestock corridors (which open up northern seasonal grazing areas) is almost certainly better than the payoff from a marginal expansion of the farmed area. The latter leads to the twin problems of damage to crops and blocked livestock corridors, while the former is likely to improve relations as pastoralist herds are able to pass through farming areas unhindered and make stops at specific rest places. Therefore, herds are less likely to trespass on fields and damage crops. The Southern Rizeigat Tribal Administration attempts to mitigate these problems and plays a vital role in addressing disputes on a case-by-case basis. Nevertheless, this issue of farmer-herder conflict is an increasing strain on the integration of farming and pastoralism, yet it is not well understood. There has been a wide range of initiatives to demarcate corridors, although lessons learned from this experience are not yet in the public domain.

Recommendations: Farming and herding

4. Evaluate the experience in demarcating livestock corridors, considering implications for livestock health, farming, social relations, marketing, and environmental management.

5. Conduct a land use study to analyze changes in the area devoted to crop farming, the reasons for these changes, and the implications of these changes for access to grazing land and the maintenance of livestock corridors. The objective would be to devise realistic and effective mechanisms to maintain livestock corridors, watering points, and resting places.

6. Promote a positive shift in attitudes towards pastoralism and pastoralist mobility and a better understanding of the challenges experienced in farming and pastoralism (building on Recommendation 1).

Governance of pastoralist mobility: What works? What remains to be done?

The Southern Rizeigat Tribal Administration in East Darfur plays an additional crucial role in the annual pre-migration conference with the Dinka Malual, negotiating the agreement that enables pastoralists to enter South Sudan with their herds. This agreement serves both parties well. For the Southern Rizeigat, this vital "escape hatch" reduces pressures on resources in the Bahr area in the dry season. This is especially important in drier years (such as 2015, when the rains were both delayed and below average).

While relations have improved between different land users (the Southern Rizeigat and Dinka Malual) in South Sudan, inter-tribal conflict in parts of eastern Darfur has persisted for nearly three years, leaving a trail of failed conflict resolution mechanisms. A proper analysis of these processes is overdue.

Herder-farmer conflicts are usually disputes between individual land users whose livelihoods are equally threatened. In practice, the disputes are best dealt with locally, involving local tribal leadership as needed. These disputes are sometimes tangentially linked to deeper, long-running conflicts as a result of the tribal affiliations of herders and farmers and their long and shared history. Hence, the two types of conflict are connected, but these local disputes are only superficially relevant to higher-level conflicts, while the higher-level conflicts directly impact livelihoods at a local level. It is therefore often incorrect to infer (as many external commentators do) that these local-level farmer-herder disputes are the direct or indirect cause of wider, higher-level conflicts.

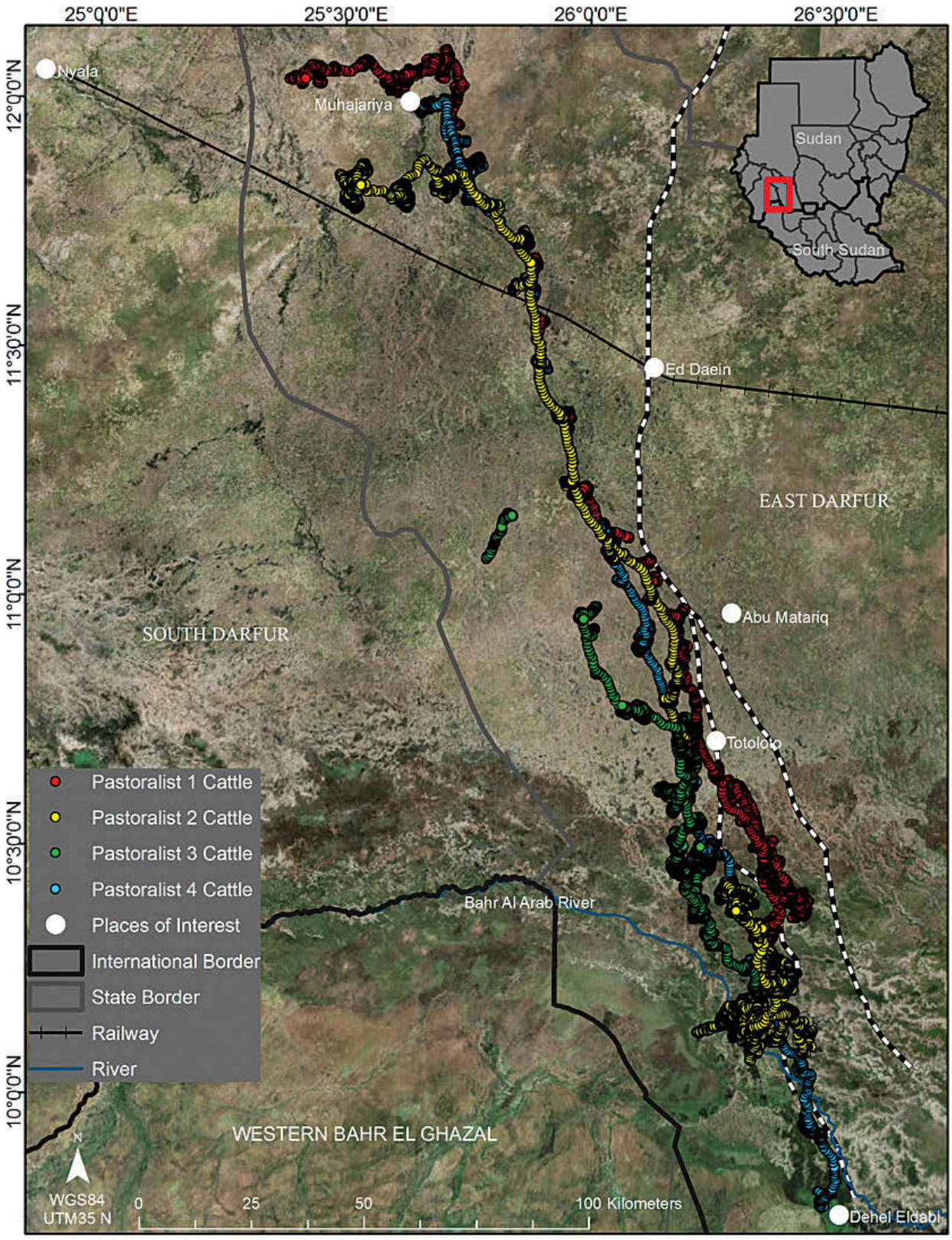
Recommendations: Governance of pastoralist mobility

7. The Southern Rizeigat and Dinka Malual pre-migration conferences and meetings should continue to be supported by donors, at least until the wider situation stabilizes.

8. Greater recognition by the national and regional authorities is required of the crucially important role of the tribal administration in supporting pastoralist mobility. Members of the tribal administration are involved in considering how the specific needs of conflict-affected pastoralist herds might be supported. The tribal administration negotiates with local tribal leaders to identify nearby resting areas and places where water and fodder supplies can be provided on an emergency basis.

9. The coordinating body of the international Livestock Emergency Guidelines and Standards (LEGS 2015) should be encouraged to review how conflict affects pastoralist mobility. The coordinating body should consider how this could be addressed by local humanitarian actors in the next edition of the Standards.

Figure 1. Map of East Darfur showing the central livestock corridor and the movements of four pastoralist cattle herds from May to September 2013.



Note the scale in Figure 1 is different to Figure 2.

Figure 2. Map of East Darfur showing the movements of six pastoralist herds from February to May 2015.

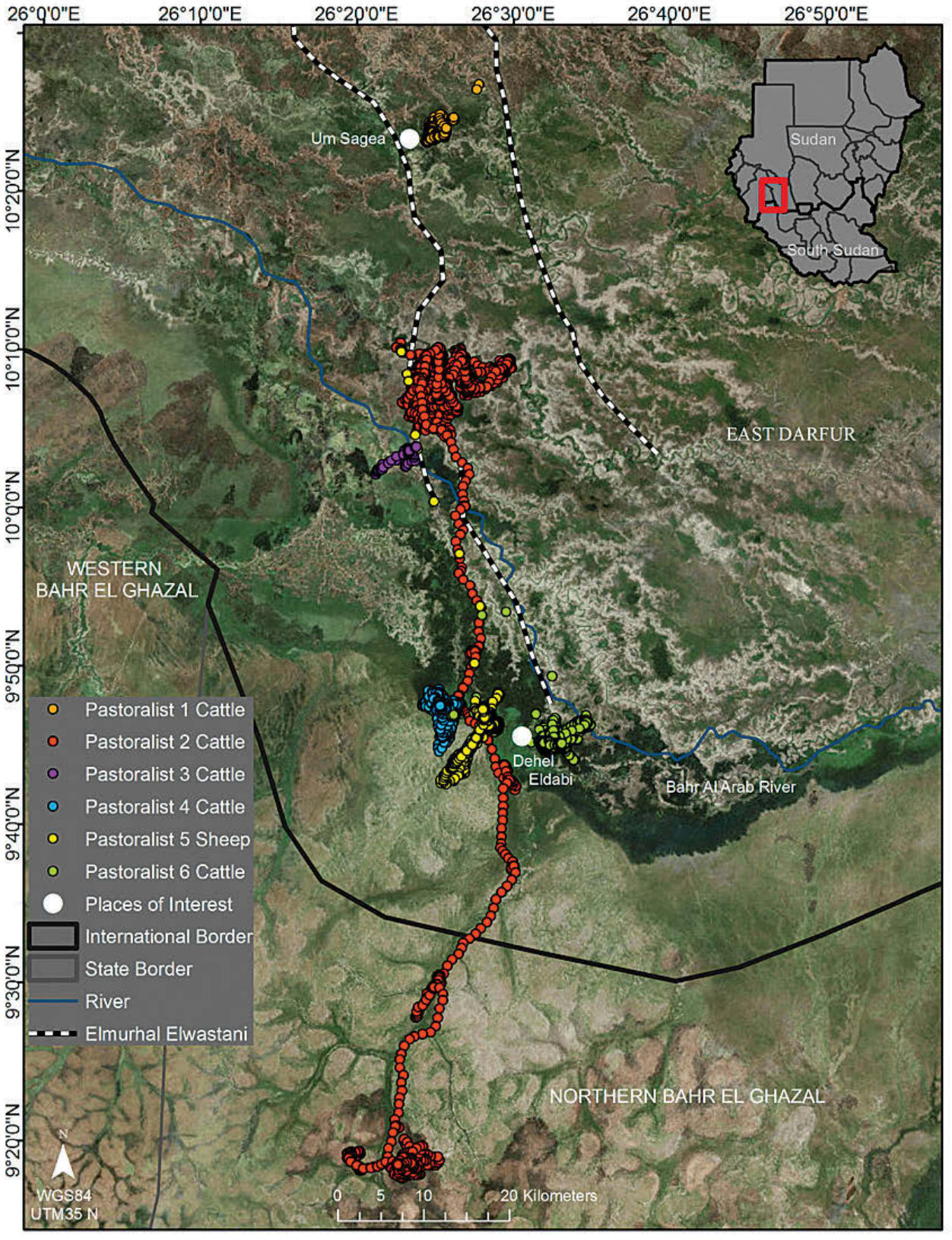


Figure 3. Map of East Darfur showing the long-term average rainfall isohyets (2000 to 2016)

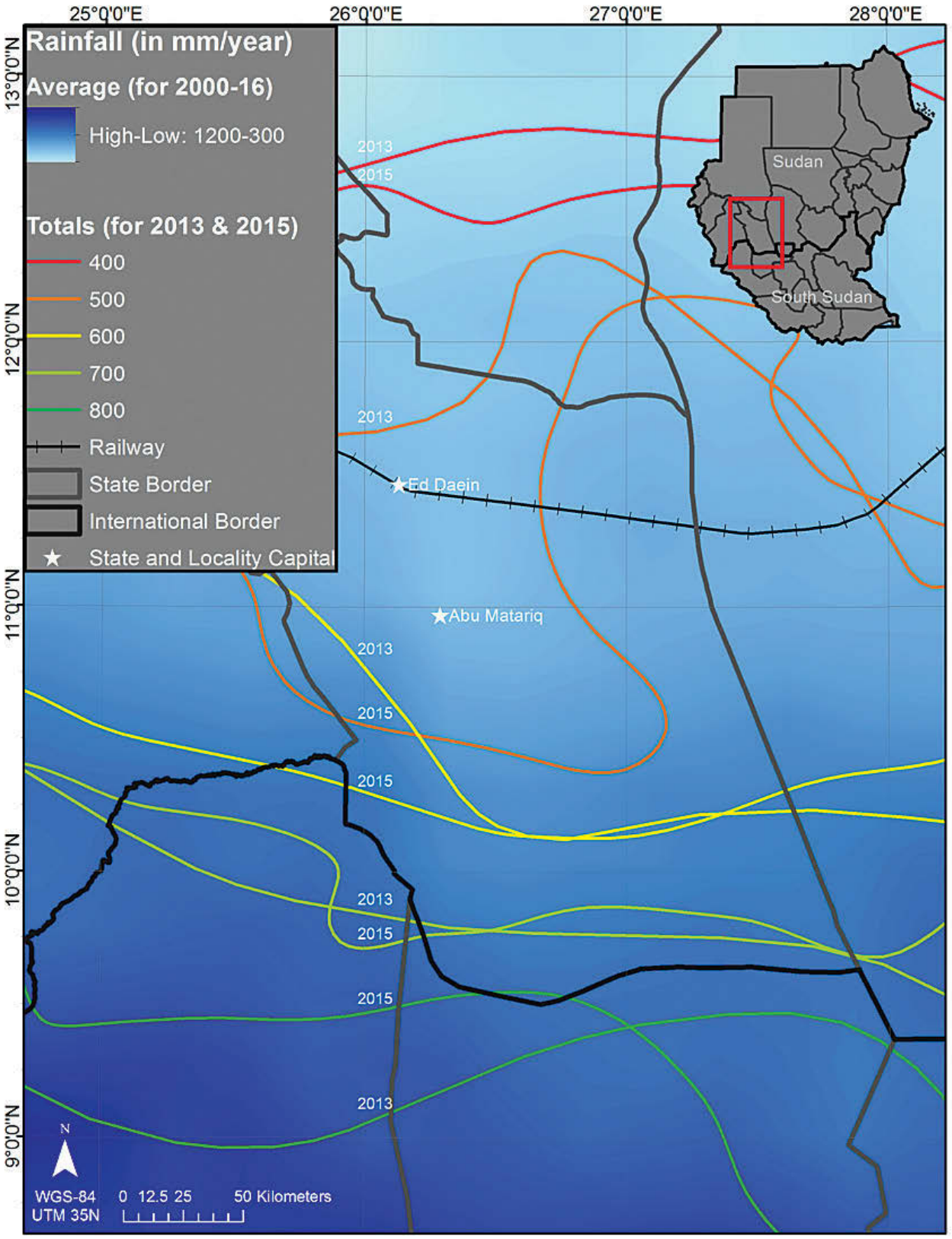
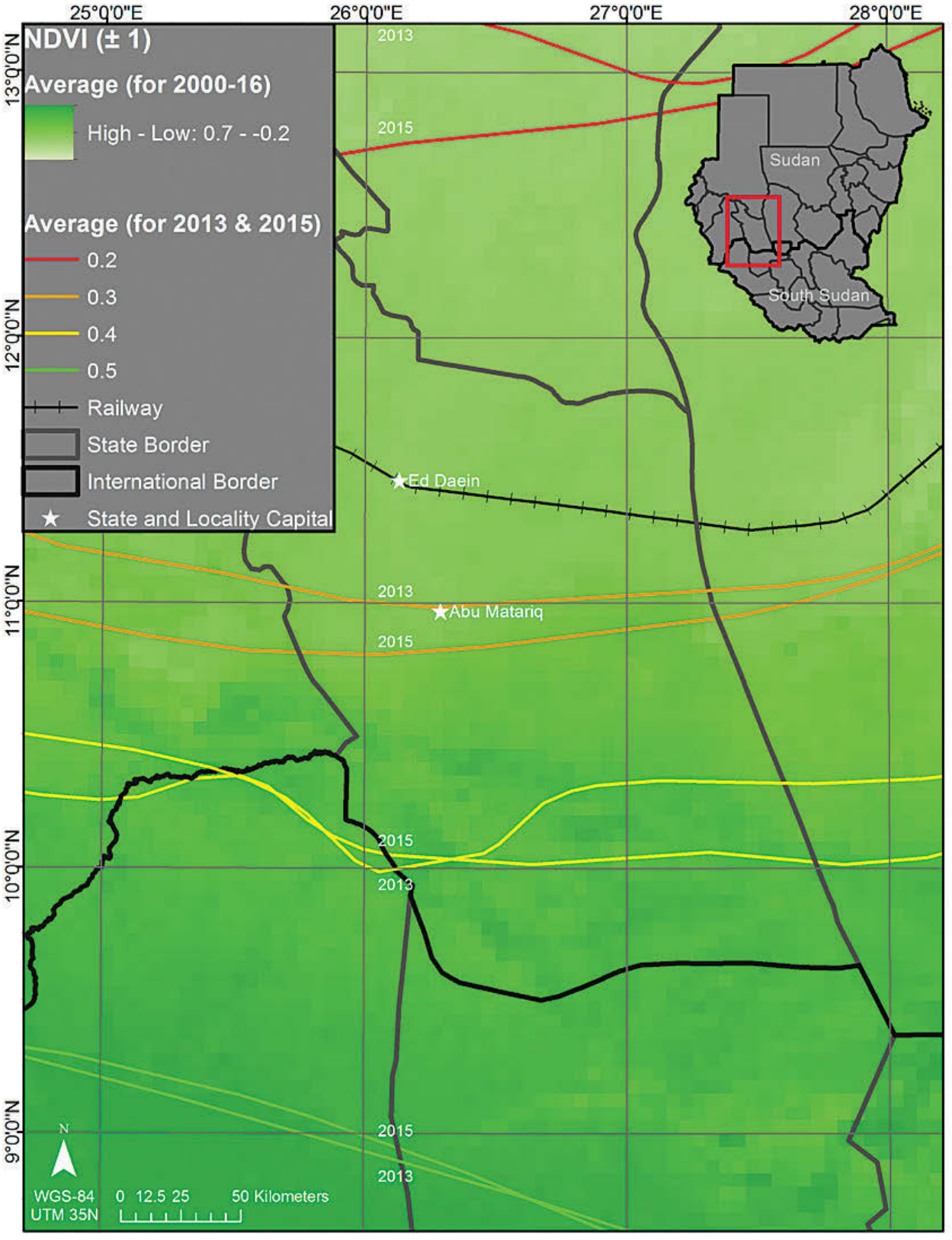


Figure 4. Map of East Darfur showing the long-term average NDVI isohyets (2000 to 2016) and the average annual NDVI for 2013 and 2015.



Introduction

The facts about the positive contribution of pastoralist livestock production to Sudan's national economy and local livelihoods are now well established (Krätli et al. 2013, Behnke and Osman 2010) and increasingly recognized by a number of regional, national, and local actors (Pica-Ciamarra, Nouala, and Kim 2011; Fahey and Leonard 2007; Fahey 2007).[2] Despite this recognition, pastoralism is still under pressure, partly as a result of an ambivalent institutional and policy context, which unwittingly undermines pastoralism. This undermining of pastoralism arises because of a lack of understanding and because attitudes and perceptions are slow to change as compared to the growing knowledge base.

This report presents a scientific account of the environmental principles of pastoralist production in the Darfur region. These principles showcase the highly strategic nature of livestock mobility and are the basis for its continuing success. Once these principles are understood, conflicts between herders and farmers over natural resources can be better recognized for what they are, disputes between individual land users whose livelihoods are equally threatened. In practice, the disputes are ideally dealt with at the local level. However, they are tangentially linked to deeper, long-running conflicts that destabilize the region and undermine livelihoods more broadly. These links between local disputes and higher-level conflict stem from the particular tribal affiliation of different land users and their long and shared history. Hence, the two types of conflict are connected, but these local disputes are only superficially relevant to higher-level conflicts, while the higher-level conflicts directly impact livelihoods at a local level.

Over recent decades, conflict has played out on multiple levels in Sudan. The conflicts have taken different forms, including inter-tribal feuding and episodes of violent conflict, rebel insurgencies and counter-insurgencies, and wider cross-border or transnational conflicts. Often these different layers of conflict are inter-connected. As we argued in an earlier report, there are structural links between land, power, and tribal politics (Young et al. 2012). For example, the escalation of local tribal conflicts over land can be fueled by the political allegiances of the users of that land and wider tribal politics. Current approaches to conflict analysis tend to focus attention on conflict players and conflict dynamics, which to some extent polarizes the groups concerned, politicizes the debate, and shifts it away from any real understanding of the way in which land and natural resources are used and managed (as common property by multiple users over time). In the meantime, the prevailing discourse attributes these local issues of natural resource competition and conflict as causal factors of the wider conflicts in Sudan. For example, an International Commission of Inquiry on the Darfur conflict placed "the competition between the sedentary tribes and nomadic tribes over natural resources as a result of desertification as the first factor causing the [Darfur] conflict, while the second was the weakening of the local [tribal administration]" (International Commission of Inquiry 2005, 57). Others have also argued "climate change, land degradation and the resulting competition over scarce natural resources are among the root causes as well as the consequences of the violence and grave humanitarian situation in the region" (UNEP 2007, 20).

The strategic mobility associated with pastoralist livestock migration is the basis for the profound ecological resilience of pastoralism. However, history has shown, in the Darfur context and elsewhere, that this ecological resilience is insufficient on its own to ensure that pastoralism is sustainable. Sustaining the pastoral system also requires compatible social and economic conditions and a supportive policy and institutional environment, in order to build "social resilience," an integral part of peace and stability. Social and ecological resilience are closely linked. Adger defines social resilience as

[2] Also see the Sudan National Five-Year Strategic Development Plan (2007–2011).

"the ability of groups of communities to cope with external stresses and disturbances as a result of social, political and environmental change" and discusses the link between social and ecological resilience (Adger 2000, 347). This approach encompasses analysis of the resilience of social and community institutions to shocks and stresses. As the evidence in this report shows, access to water and pasture by pastoralist livestock in Sudan is governed by specific institutions and customary rules and regulations, overseen by a traditional tribal administration that promotes and protects social and ecological resilience. This is important in relation to the resilience of all livelihood systems in the region. It is also vital to the wider economy, local livelihoods, cross-border peace and reconciliation, and wider peace-building and recovery in Darfur.

The first phase of this work under the UNEP Sudan Integrated Environment Programme (SIEP) argued that seasonal patterns of natural resource availability determine the timing and direction of herd movements (Young et al. 2013). This is evidenced by the northerly migratory movements moving in tandem with the advancing rains and localized greening-up of the vegetation. The report (Young et al. 2013) explains how pastoralist migratory movements are technically sophisticated and effective for redistributing grazing animals over space and time.

The first part of this report provides the scientific rationale for why the pastoralist herds move (pastoralist mobility) in relation to biophysical parameters (rainfall, plant growth, forage quantity, and water quality and availability during the dry season) as well as push factors and unexpected events, including insecurity and drought. Part Two describes how the pastoralist livelihood systems work in practice in terms of livelihood diversification, integration with markets and trade, and gender roles and responsibilities. Part Three reflects on the social and economic integration of pastoralism with other livelihood systems and reviews local governance systems for regulating and managing pastoralist movements and interactions with others. Finally, the conclusions draw out the main lessons learned and some preliminary recommendations to be reviewed with national and international stakeholders.

Methods

The methodology builds on a wealth of experience monitoring migratory behaviors, including wildlife researchers tracking free-ranging animals and anthropological studies of livestock movements.

The report includes data from two independent yet related studies: a pilot longitudinal study of six pastoralist herds from May to September 2013[3] and a follow-up study of the same pastoralists in 2015 from February to May. The longitudinal study in 2013 was designed to capture the seasonal dynamics of herd management and livestock migration, while exploring some of the practical challenges of field research on pastoralism in Darfur. Field methods included semi-structured interviews, weekly telephone interviews where possible, monthly outreach visits, and GPS tagging of four of the six cattle herds. The earlier report provides full details of the purposive selection of the six pastoralist producers and profiles of their livelihoods (Young et al. 2013).

The 2015 study monitored the movements of the original six pastoralist cattle herds and three sheep herds owned by the same pastoralists. The pastoralists are referred to in this report as Pastoralist 1 to 6, followed by the livestock species, sheep or cattle.

Partners and research personnel

An important part of this work was working with national, regional, and local stakeholders, including the Federal and State Ministry of Livestock, Fisheries and Rangeland, national NGO Al Massar Organization for the Development of Nomads, and SOS Sahel Sudan. We also worked with the senior tribal leadership responsible for the management of livestock corridors in Eastern Darfur. The role of the team from the Feinstein International Center at Tufts University Friedman School of Nutrition Science and Policy was to provide technical leadership and support for the research, while local NGO partners supported the organization of fieldwork and logistics and, most importantly, maintained ongoing communications with their constituencies and other local stakeholders in the region. The two State-level Ministry personnel brought their considerable veterinary expertise. They provided extensive national and local experience, combined with an in-depth knowledge of the study area and its people. For example, at the startup of the research, one of the veterinarians gave the animals a general health check before tagging them with the GPS device.

The GPS tagging devices and livestock collars

The 2013 and 2015 studies used two different archival battery-powered GPS tagging devices, produced by Skorpa Telemetry. These are compared in Annex 1. The "Microtrax Pathfinder" used in 2013 suffered from a short battery life (less than 120 days), requiring frequent outreach visits. The 2015 study used an improved version, known as "Snaptrax," which operates by regularly taking a series of "snapshots" for between 64–512 milliseconds (ms) and then turning off.

The 17 gram tag, with a small patch antenna, was solid potted and encased in Acrylonitrile Butadiene Styrene (ABS) plastic, which provides protection against dust and is durable. The small connector plug on the device for charging and downloading data was protected by an additional sealed putty plug. A local leatherworker produced sturdy leather livestock collars with pouches to contain the devices, which were sewn in and thus difficult to remove without destroying the pouches. In 2015, we programmed the devices to take GPS recordings every 15 minutes for 180 days (although this was not achieved due to short battery life). The devices recorded three readings every 15 minutes, which were then averaged to provide a single GPS reading for location.

Out of nine devices that were fitted at the start, we retrieved eight at the end. This is

[3] This was part of an operational research program under the UNEP SIEP (Young et al. 2013).

remarkable given the study duration was extended from 4 months to 11 months before we returned to collect the devices. After such a long period fitted to livestock, the leather casings were generally in good condition and data were successfully downloaded and decoded for six of the eight devices (five cattle and one sheep herd).

Data and analysis

2013 questionnaire data

During the 2013 phase of livestock monitoring, the six cattle pastoralists from East Darfur were interviewed regularly. We conducted a total of 226 interviews, 44 among cattle herders in East Darfur, 81 among camel herders, and 101 among sheep herders in North Kordofan. The telephone questionnaire covered the following topics:

- location since last interview
- rainfall characteristics
- land or soil type
- watering of the herd
- grazing quality and crowding
- grasses, trees, and shrubs eaten by livestock
- crop residues
- pests; livestock health and services used
- sale of livestock and livestock products

Remote sensing and analysis

We conducted NDVI (Normalized Difference Vegetation Index)[4] analysis to (1) provide descriptions of how phenological (plant life cycle as influenced by climate and habitat) variables change over space and time and (2) to examine the relationship between phenology and livestock movements.

As part of the NDVI analysis, we compared seasonal profiles of biweekly NDVI across the five pastoral zones in Sudan that were identified by pastoralists. A sixth zone, the Butha, was excluded as it falls wholly within South Sudan, which was not visited. Therefore, it was harder to select a typical area. We used a 20 x 20 km sample taken from each pastoral zone (Figure 5a). The selection of these five pastoral zones was based on field visits and consultation with pastoralists and local experts. These pastoralist zones should not be confused with the classification of ecological zones by Harrison and Jackson (1958). They do bear some strong similarities to the planning classification maps by Huntings Technical Services in the 1980s (HTS 1985). These similarities warrant further examination.

We also carried out analysis of the NDVI coefficient of variation (CV), the maximum NDVI, and the minimum NDVI. To investigate the relationship between the changing vegetation and livestock movements, we calculated the NDVI values for the actual area occupied by the herd for each day. We divided the GPS locations into daily records and then converted them to a "line" showing direction of movement. We created a buffer zone around each daily line (plus or minus 600 meters from the GPS location). This buffer zone was used to extract the mean NDVI values for each of the 23 biweekly NDVI layers for 2015.

Direction and movement of pastoralists

The livestock collar devices recorded data every 15 minutes. We aggregated the data to daily locations by selecting the single location closest to midnight (Coordinate Universal Time (UTC) every day. We selected the first location of each week of the collar dataset, starting on the first full 24-hour period of data for the weekly aggregates. This allowed us to examine daily and weekly movement patterns.

We calculated distance, direction, and movement angle between each of the daily and

[4] The NDVI is a parameter based on an algorithm that employs satellite reflectance data in two spectral bands to compute a single index that is now the most common means used for mapping the surface distribution of vegetation at the earth's surface and for determining the temporal cycles (or phenology) of the vegetation (Pettorelli et al. 2011). The relation is based on the observation that chlorophyll has a higher reflectance of sunlight in the near infrared compared to the red portion of the spectrum. The higher the NDVI, the more vegetation cover or biomass within a pixel. Such kind of remote sensing analysis affords information needed to understand decisions taken by pastoralists, and it also benefits different policy initiatives. Inter-annual and intra-annual (seasonal) phenological parameters for the study region were based on MODIS (Moderate Resolution Imaging Spectroradiometer) biweekly NDVI at 250 m spatial resolution extended from 2000 up to 2015. The smoothed version of NDVI time series produced by the University of Natural Resources and Life Sciences of Vienna (**http://ivfl-info.boku.ac.at/index.php/eo-data-processing**) was used.

weekly locations in R (R Development Core Team 2014) using the "adehabitat" package (Calenge 2015). We used these data to calculate cumulative daily movements to the north and south.

Precipitation data

We acquired daily precipitation data from ERA-Interim dataset of the European Centre for Medium-Range Weather Forecasts (ECMWF) for the years 2013 and 2015. Monthly means for the period 1979 to 2014 generated long-term means for five of the six pastoral zones.

The ERA-Interim data consists of global atmospheric reanalysis from 1979, continuously updated in real time. The precipitation data from these datasets are based on a reanalysis created via a data assimilation scheme and models that process observations from radiosonde, satellite, buoy, aircraft, and ship reports every 6–12 hours (Dee et al. 2011). This gridded dataset had the advantages of being available up to 2015 and being straightforward to acquire and process. Moreover, as it does not depend on gauge data, it is an alternative to using data from land stations (such as products from the Global Precipitation Climatology Centre (GPCC)) in regions where these are sparse, as in Darfur.

On the other hand, over the duration of each reanalysis product, the changing observation mix can produce artificial variability and spurious trends. Comparisons with independent gauge-based gridded products such as those from the GPCC show that, over land and in non-mountainous areas, the correspondence of monthly mean precipitation rates is very close (Dee et al. 2011). The accuracy of daily rainfall estimates could not be verified against station records, but the correlation between ERA and GPCC monthly means for Africa is between 81 percent and 84 percent. ERA rainfall estimates are higher than those of GPCC by around 0.25 mm/day, but this may be related to under-catch at gauges where rainfall is low (Simmons et al. 2010).

The ERA rainfall data were downloaded for 12-hour steps from 0:00 and 12:00 UTC and processed to daily composites. The daily rainfall data were extracted for the daily and weekly pastoralist locations, and monthly data extracted for the five pastoral zones using the same 20 x 20 km blocks referred to above.

Strengths and limitations

GPS tagging devices

The 2015 study adopted a new type of archival device, with a claimed longer and more predictable battery life. However, the devices operated for about 90 days versus the predicted 180 days. The devices remained on the livestock for up to nine months, yet only three to four months of data were recovered, which was a major disappointment. The manufacturer, Skorpa Telemetry, went out of business in 2015. On the other hand, the device retrieval rate was high for both studies. In 2013, four out of four devices were recovered from herds, and, after nine months in 2015, eight out of nine devices were recovered. This recovery rate is remarkable and is a testament to the interest and commitment of the pastoralists recruited into the study and the support given by the local tribal leaders and Ministry personnel.

Small sample size versus considerable depth and breadth of data

The study started in 2013 as a pilot. It included six pastoralists in East Darfur and six in North Kordofan and collected from between four and seven months' worth of data, with some gaps. We developed the follow-on study to complete the annual cycle by monitoring mobility at other times of the year. However, the second study was significantly delayed, and monitoring only started in early February 2015. It continued to May of that year (at which point the device batteries ceased to operate). Thus, the second study covered only the hot dry season, when livestock are in the southern part of their migratory cycle close to permanent water sources, or large herds are traversing into South Sudan seeking pasture and water. While the sample size is small, the continuous GPS monitoring over time, combined with remote sensing data, provided an unprecedented opportunity for analysis of pastoralist livestock movements.

Closure and restart of the project

The second phase of livestock monitoring was affected by the closure of the project from the end of February 2015 to November 2015, when it was restarted. During this time, project staff and project partners continued to maintain contact with the pastoralists in the study, assur-

ing them that we were hoping to be able to return to collect the devices. The successful completion of this study is therefore largely due to the commitment of the national research team and partner organizations, who continued to support the work throughout.

Access and security; limited access for international researchers

International researchers were unable to travel to East Darfur, and so the national researchers played a vital role in managing the work locally.

Part 1. The seasonal imperative: Environmental drivers of livestock mobility

The study area—Why move?

The migratory routes examined in this report traverse up to 400 kilometers or more along a north-south transect in a single year. The pastoralists who travel these routes cross what they recognize to be six distinct pastoral zones. Four of these zones lie within Sudan, one straddles the border between Sudan and South Sudan, and the sixth most southerly zone lies entirely in Dinka country in South Sudan (Figure 5a).

In the course of a year, each of these environments provides conditions and resources that are favorable for livestock production, but at other times of the year pose problems. Seasonal migration in East Darfur is all about using an area when conditions there are favorable, and avoiding it when conditions deteriorate: seizing opportunities and evading hazards. Generally, the southern parts of East Darfur are too wet for livestock during the rains, exactly when northern pastures are wet enough. Conversely, northern areas lack forage and water during the dry season, when these resources are available further south. The overall pattern of movement is therefore an annual oscillation, north during the wet season and south during the dry season (Figure 5b).

Beyond these generalizations, a more precise understanding of migratory movement requires an understanding of the seasonal attributes of the different environments used by the herds. The pastoral zones recognized by pastoralists in East Darfur correspond closely to the "land systems" employed in the 1970s by Huntings Technical Services (HTS) and other observers (Christian 1958; Harrison and Jackson 1958) to classify the landscape of East Darfur. These land systems consist of "physiographic units … each with a recurring pattern of geomorphology, geology, soils, vegetation and drainage" visible from aerial photography, satellite imagery, and ground observations (HTS 1975a, 2). In other words, each land system constitutes a "package" of biological and physical attributes linked to one another and visible both to outside observers and local land users.

Based in part on the boundaries of the corresponding land systems identified by HTS, the locations of five of the six pastoral zones that constitute the East Darfur migratory circuit are given in Figure 5a.

In topographical terms, these pastoral zones constitute a series of relatively elevated or depressed areas associated with different combinations of clay and sand soils. The more elevated zones, which occur in the extreme north (the Goz) and to the south (the Boroya) of the study site, have light sandy soil. Heavy clay soils occur in low-lying zones adjacent to two west-to-east flowing drainage systems that eventually feed into the Nile. These are the Bahr al Arab near the Sudan/South Sudan border (Bahr pastoral zone) and the Lol River in South Sudan (the Butha zone). Two transitional pastoral zones lie in the middle of East Darfur. They are the Dahara, which is adjacent to the Bahr, and the Atmur, which is further to the north and borders on the Goz. These zones are intermediate in their geographical position (between Goz and Bahr), in their elevation, and in their soils, which are a mixture of clay and sand.

Cutting across the topographical pattern described above are predominately latitudinal climatic regularities. The rainfall regime in East Darfur is monsoonal. The annual rainy season begins in the south of the study area and shifts northward over several weeks. The rains in the north of the study area therefore begin later, but they also finish sooner and, on average, are not as heavy over the course of the year as in the south (see Table 1).

Taken in combination, topography, soils, and climate have created an extremely heterogeneous environment in which to practice livestock keeping in East Darfur and adjacent areas of South Sudan. Table 1 provides an overview of the main environmental features of the six pastoral zones crossed by the central corridor (*Almurhal Alwastani*) of East Darfur. Table 2 characterizes each of these six zones in terms of the seasonal occurrence of resources and risks for pastoralism. The biophysical variables that control this movement system are described in detail in subsequent sections of this report.

Figure 5a. Pastoral zones in eastern Darfur.

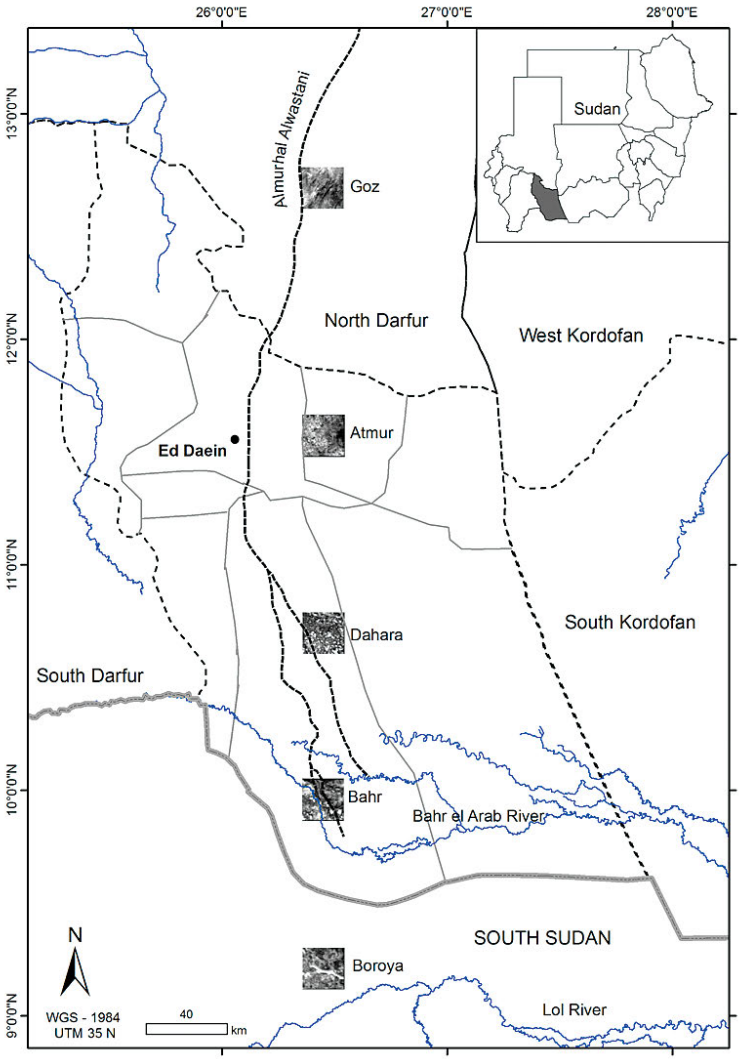
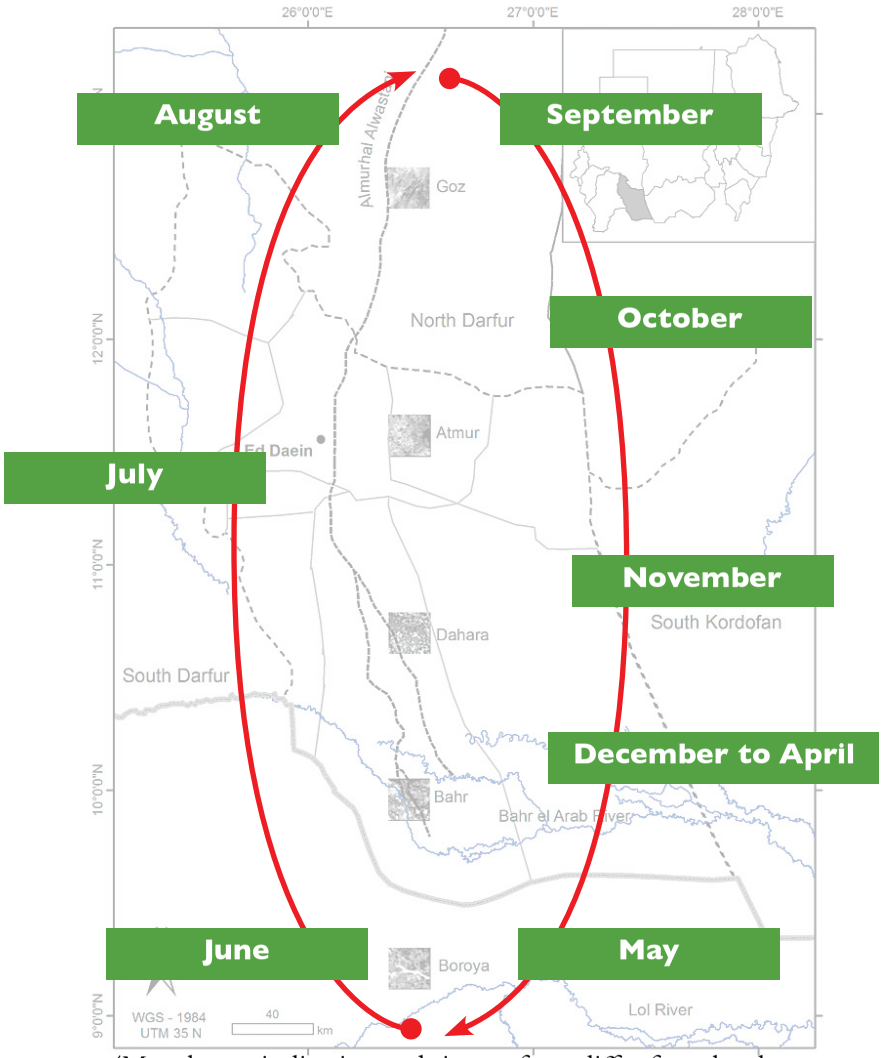


Figure 5b. Schematic migratory cycle for cattle pastoralists in eastern Darfur.



(Months are indicative; real times of use differ from herd to herd and from year to year).

Table 1. Natural features of the pastoral zones along the central livestock corridor of East Darfur

Cardinal direction	Pastoral zone	Distinguishing feature	Topography	Soils	Natural water sources	Mean mm annual rainfall, 1979–2014
North ↑	Goz	Gently rolling, stabilized dunes	Sand sheet	Stabilized wind-blown sands	Poor; temporary rainwater pools in depressions	487
	Atmur	Soil suitable for cultivation; not seasonally flooded	Alluvial plain with isolated sand dunes	Mixture of clays and sand depending on elevation	Small ponds in river beds and rainwater pools	781
	Dahara	Seasonally flooded	Broad, meandering channels and oxbows, lakes, and clay depressions	Mixture of clays and sand depending on elevation	Standing water four months of year, some perennial	956
	Bahr	Annually inundated	Floodplain of the Bahr al Arab River	Predominately heavy, cracking clays	Natural lakes, river meanders, rainwater pools, hand-dug wells in river bed	1,103
	Boroya	No permanent water	Plateau between Bahr al Arab and Lol rivers	Sand	Temporary surface water after the rains	1,206
↓ South	Butha	Year-round water and forage	Lol River floodplain	Cracking clays with coarser soils on ridges	Rivers, water courses (*kheiran*), swamps, and lakes	No data

Table 2: Environmental advantages and disadvantages of the different pastoral zones for livestock production

Cardinal direction	Ecological zone	Season of use	Opportunities	Hazards
North	Goz	Rains	Nutritious wet season grazing	Limited water and inadequate dry season grazing
	Atmur	Rains and again in the early dry season	Suitable for farming	Trespass on cultivated fields
	Dahara	Early rains and again in the early dry season	Good water and forage in transition from wet to dry season	Mud, flies, and flood in the rains
	Bahr	Mid to late dry season	Good dry season water and forage	Mud, flies, and flood in the rains
	Boroya	End of dry season, first rains	Plentiful standing hay, browsing, and early rains	No permanent water sources
South	Butha	End of dry season, first rains	Perennial water, plentiful grazing and browsing	Must exit in time to cross the Bahr and migrate north; civil insecurity

Rainfall events and nomadic response

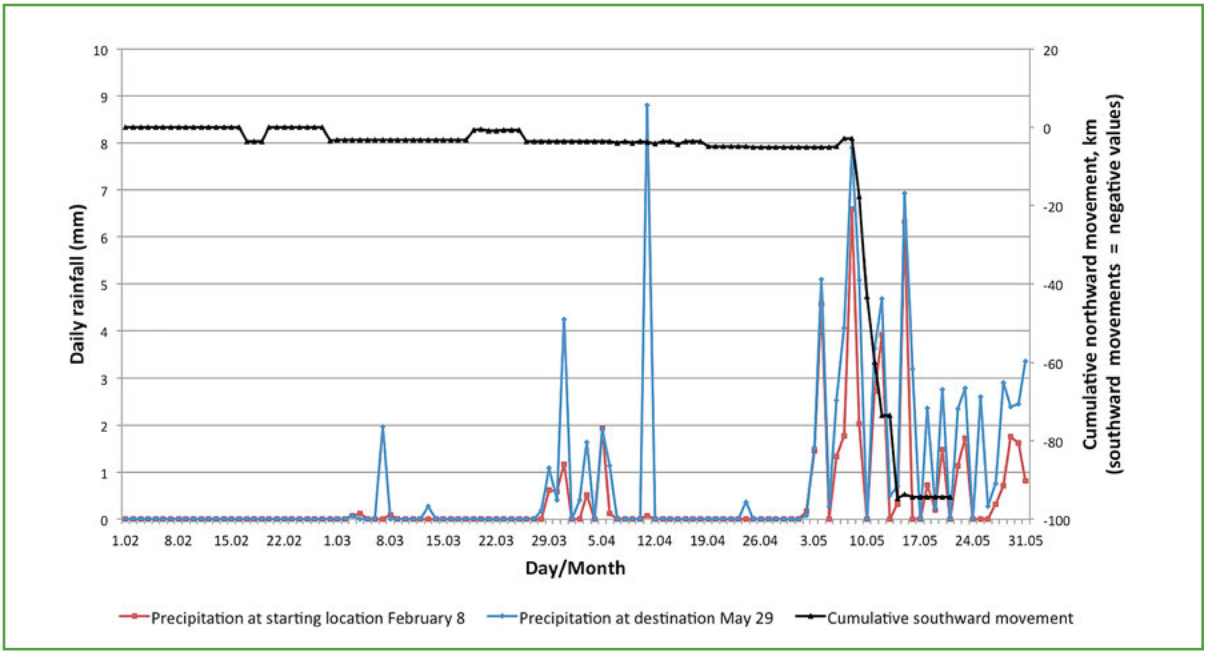
It is commonly said that pastoral nomads and their herds chase the rains. This part of our analysis examines the relationship between individual migratory moves and specific rainfall events. We will examine this relationship during two time periods, at the transition from the dry to the wet season in the far south of the study area and in the middle of the wet season as herds follow the northward progression of the rains.

Rushash—*the onset of the rains in the Boroya*

Livestock congregate in large numbers in the Bahr in the middle of the dry season to take advantage of good supplies of water. However, forage begins to run out at the end of this season because of the high concentration of animals in a limited space. Livestock are generally confined to the narrow floodplain of the Bahr al Arab River and are clustered around the remaining operational water points. Faced with these constraints, as the dry season comes to a close in the Bahr, many herds sprint south into the Boroya, where the rains have already broken and there is plentiful standing hay and browse, but as yet very little fresh grass. This move is timed to the appearance of rainwater pools that provide drinking water for the livestock. The initial move is in the direction of sufficient water, which is located by scouts sent ahead on horseback. Only later, when rainfall is more general, are pastoralists able to select grazing areas on the basis of forage quality.

The southern move of Pastoralist 2 Cattle (ED2C-15) fits this pattern. The move occurred in the second week of May 2015 following a period of unusually intense and sustained rain in the first two weeks of May (Figure 6).

Figure 6. The cumulative southward movement of Pastoralist 2 Cattle from February to May 2015 and the daily precipitation at the starting location of migration and at the destination location.



Note: northward movements = negative values. Rapid and consistent southward movement (black line, negative values) began seven days after the onset of persistent rainfall at the destination (blue line).

The dash into the Boroya has at least two advantages. Initially, the kind of forage does not change and is dry grass and browse as in the Bahr. However, there is more of it, because there are fewer livestock in the Boroya, which has no permanent water and is effectively closed to grazing earlier in the dry season. Then, as the rains develop, the dash to the south also puts the migrating herds in a position to meet the advancing front of rain several weeks sooner than they would have if they had stayed in the Bahr. Pastoralists thereby shift to fresh grass for their herds that much earlier.

Figure 6 illustrates the close coordination between the timing of rainfall events and the timing of herd movement into the Boroya. It remains to be seen if the direction of herd movement can also be linked to the locations where early rainfall has been particularly heavy. Figure 7 maps the movement of Pastoralist 2 Cattle from the Bahr to the Boroya in 2015.

In 2015, significant rain fell to the south of the reference area in late March and early April. This was followed by three nearly rainless weeks. The rains began again in earnest in the week ending on May 3 and were reasonably continuous thereafter.

Pastoralist 2 Cattle began rapidly moving south into the Boroya on May 17, 2015, two weeks after the rains began in earnest. Figure 8 plots the distribution of rain in the weeks immediately prior to that move. While the experience of one herder in one year is insufficient to draw firm conclusions, Figure 8 suggests that Pastoralist 2 Cattle were moving in the direction of an advancing rainfall front, not pursuing an isolated rainfall event. This conclusion is supported by the panel in Figure 8, which shows the herd moving south along a riverbed. Apparently, Pastoralist 2 Cattle were following not the storm itself but a topographical feature that would collect and hold rainwater in pools suitable for watering livestock.

Figure 7. Migration south at the end of the dry season by Pastoralist 2 Cattle, 2015.

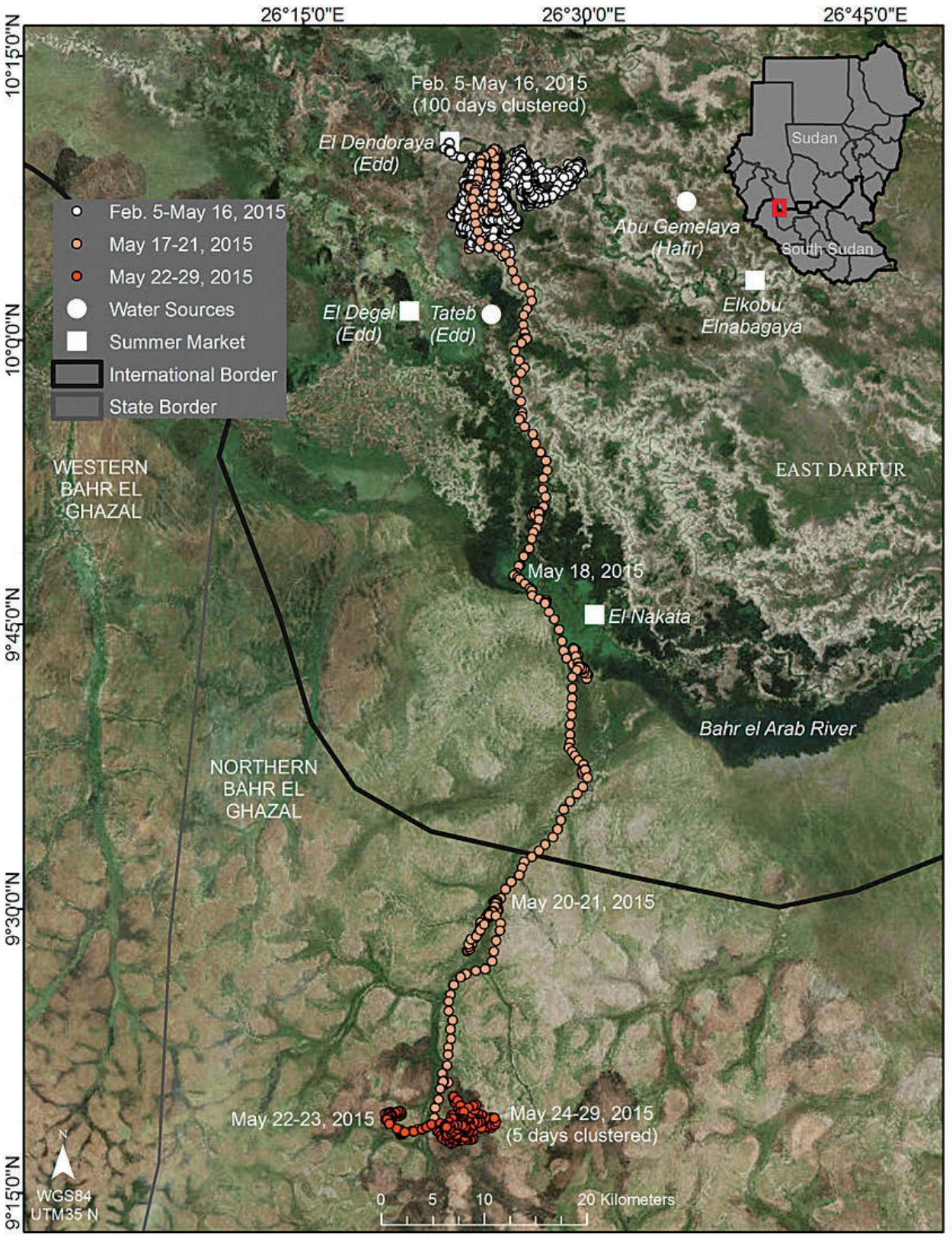
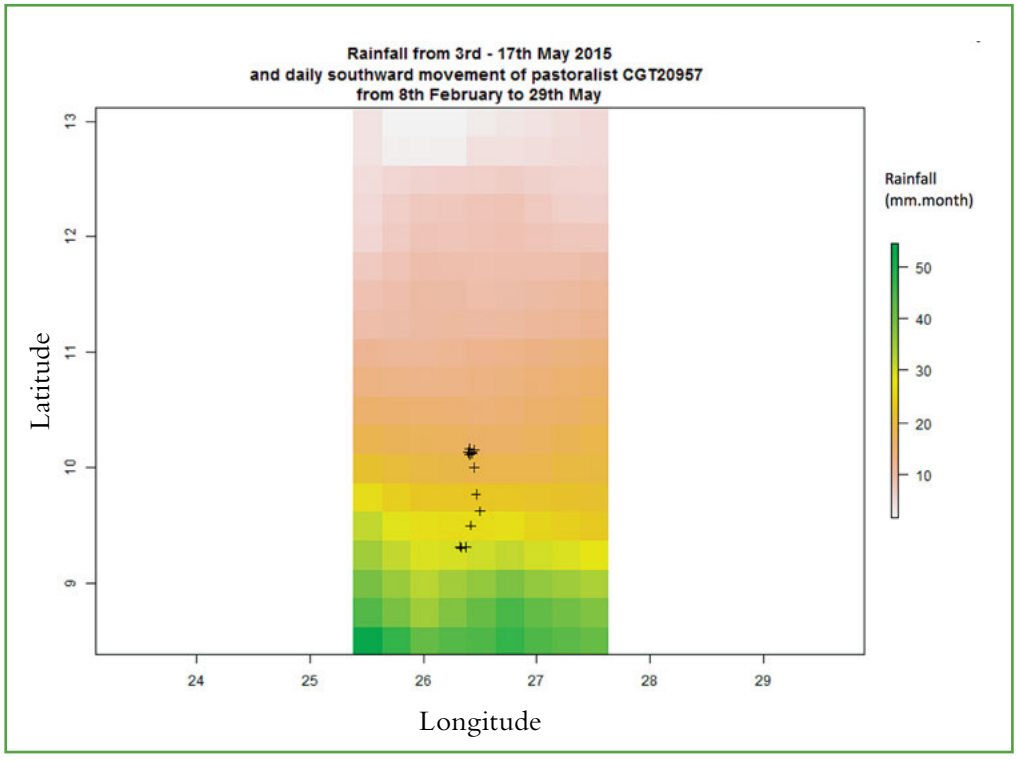


Figure 8. Panel representing eastern Darfur showing total rainfall between May 3 - May 17, 2015 and daily southward movement of Pastoralist 2 Cattle from February 8 -May 29, 2015.



Movement in the middle of the rainy season (kharif), 2013

Across the study area as a whole, in 2013 there were 14 rain days in May, 21 in June, and 30 in July. Rain days then fell back to 21 in August. The rains in May were small—under 8 mm—and concentrated in the southern half of the study area. By June, the rains were more general and occasionally larger—12–16 mm—but still concentrated in the south. By July, it was raining somewhere almost every day, and very occasionally the rain was stronger in the north than in the south. By August, the number of rain days had declined to 21, but the heaviest rain was now falling in the northern part of the study area. At least in 2013, the size of individual rain events built from May to August and moved north. This progression is depicted in Figure 9, which consists of 19 panels showing the amount and distribution of rainfall by week, from May to September 2013. Figure 10a and 10b plot the movements of two herds, Pastoralist 1 Cattle and Pastoralist 4 Cattle, on a weekly basis over the same time period, relative to the location of particularly heavy rains in early August of 2013 (Figure 10 c and d).

Figure 9. The amount and distribution of rainfall by week from May 24 to September 27, 2013.

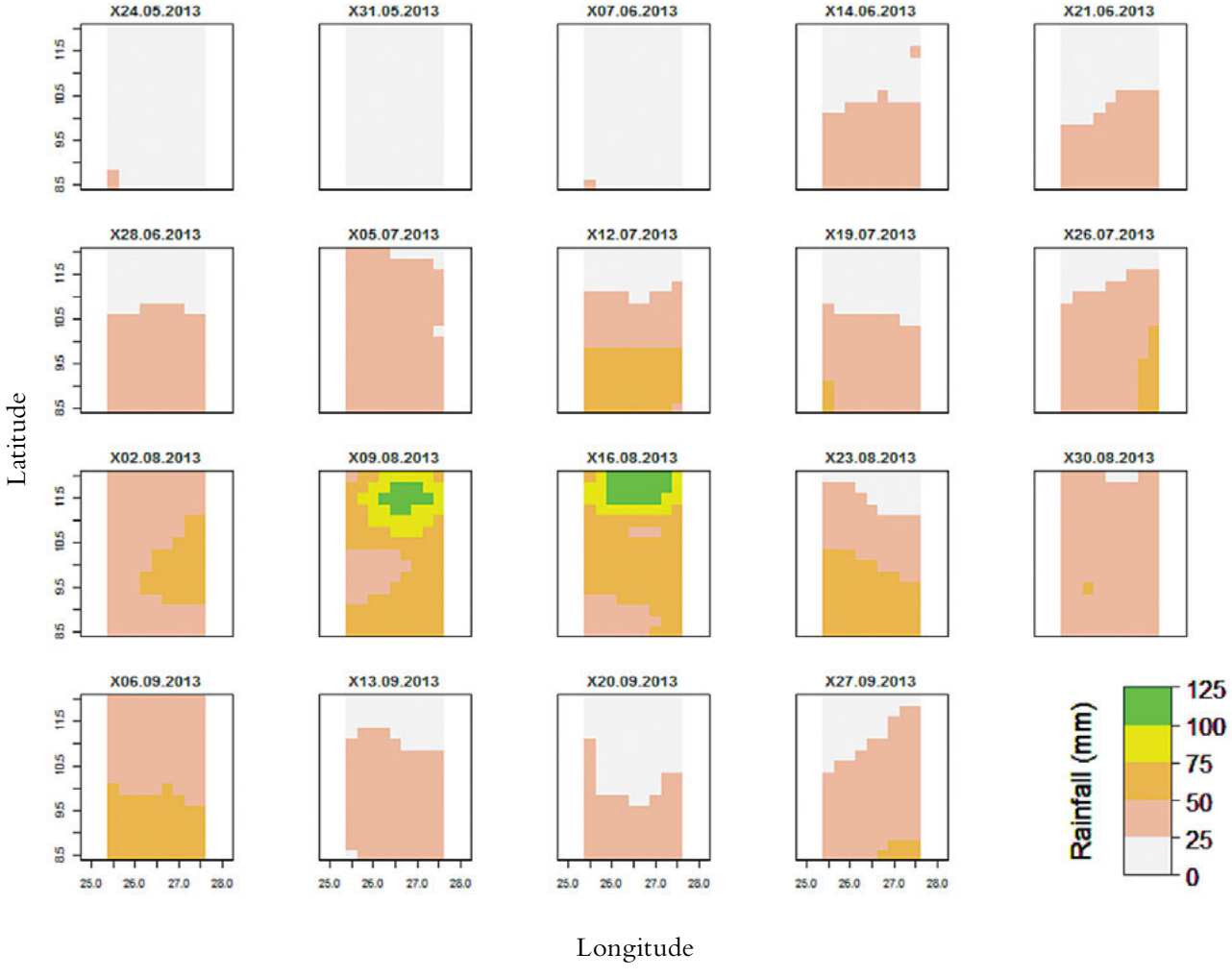


Figure 10a. The daily movement of Pastoralist 1 Cattle, 2013.

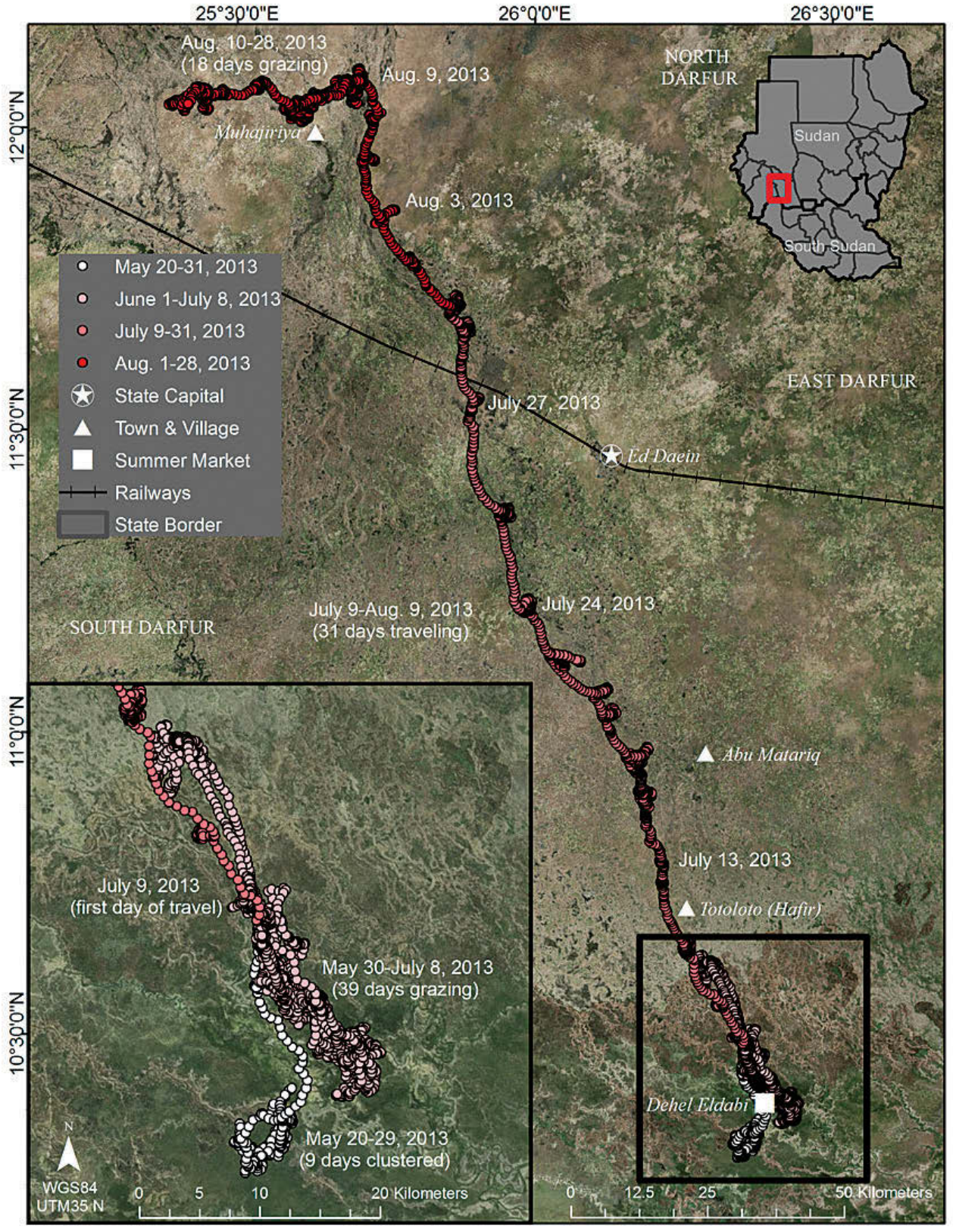


Figure 10b. The daily movement of Pastoralist 4 Cattle, 2013.

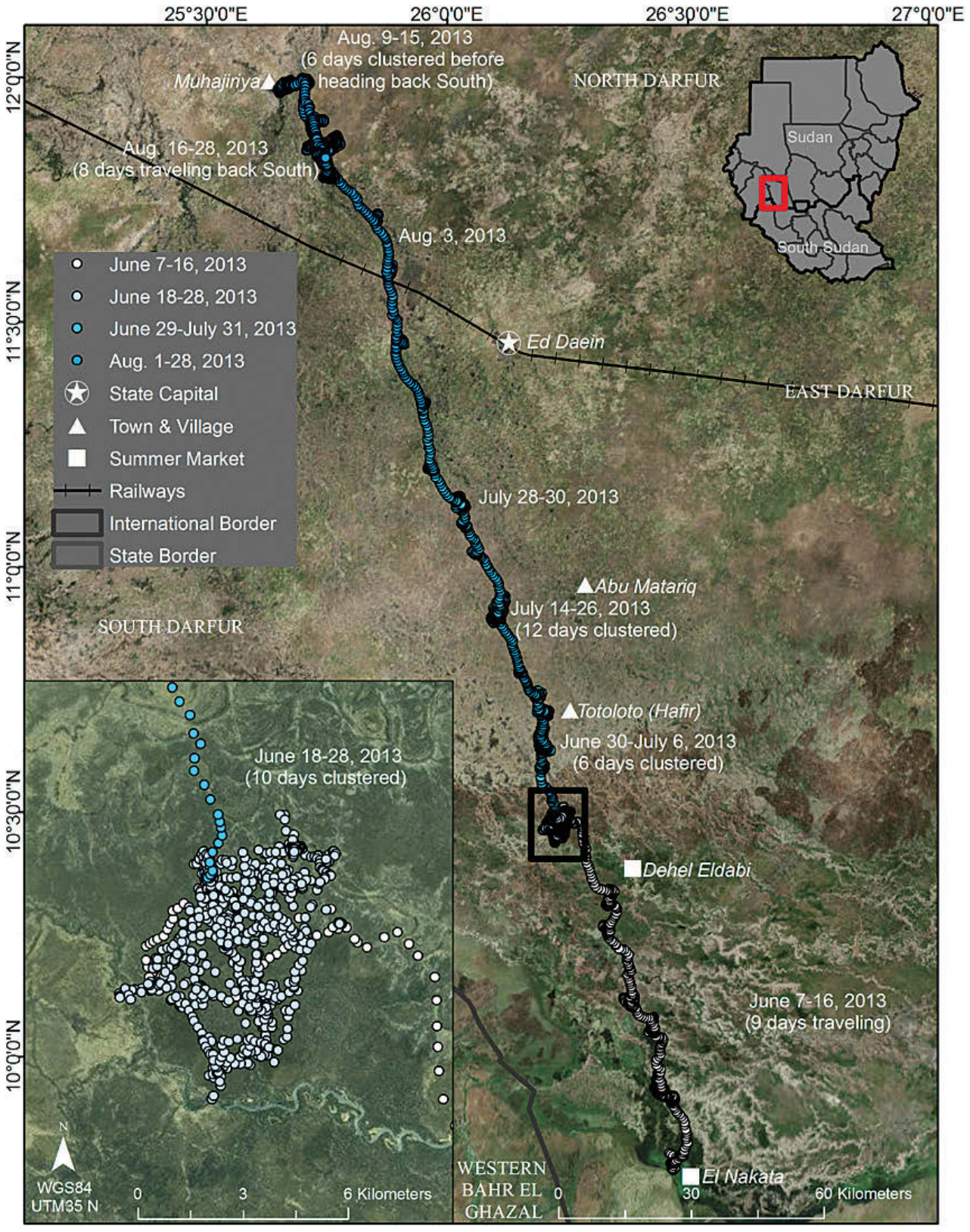


Figure 10c. Northward movement of Pastoralist 1 Cattle from May 28 to August 28, 2013 and the total weekly rainfall beginning August 9, 2013.

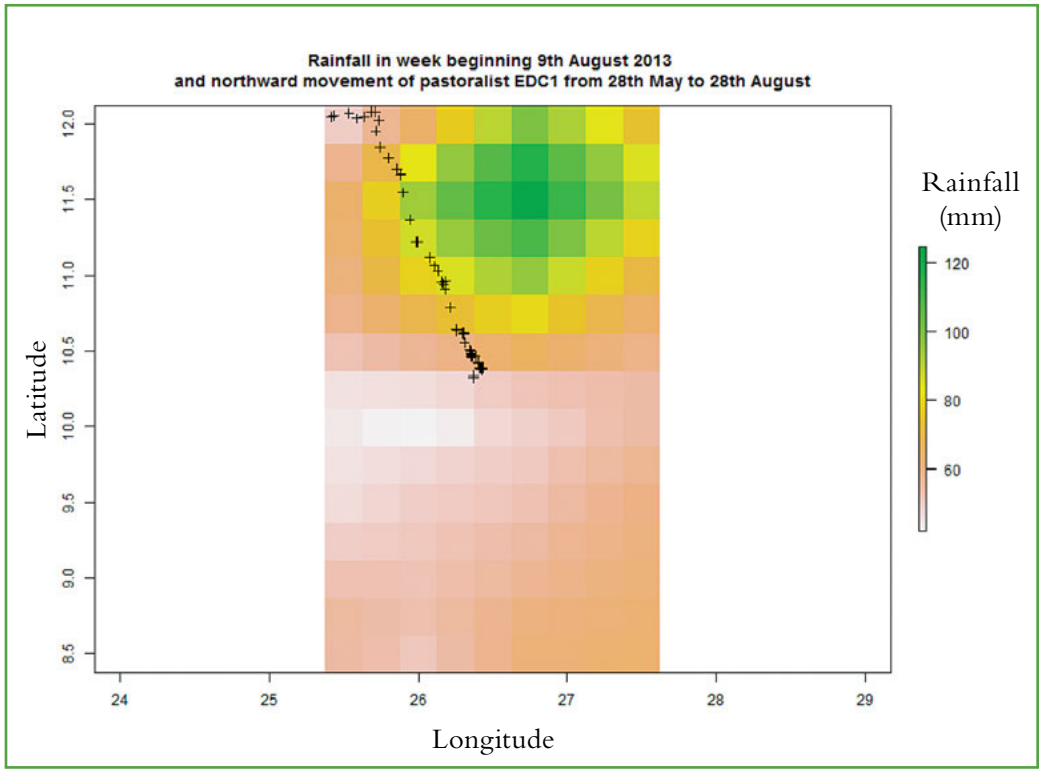
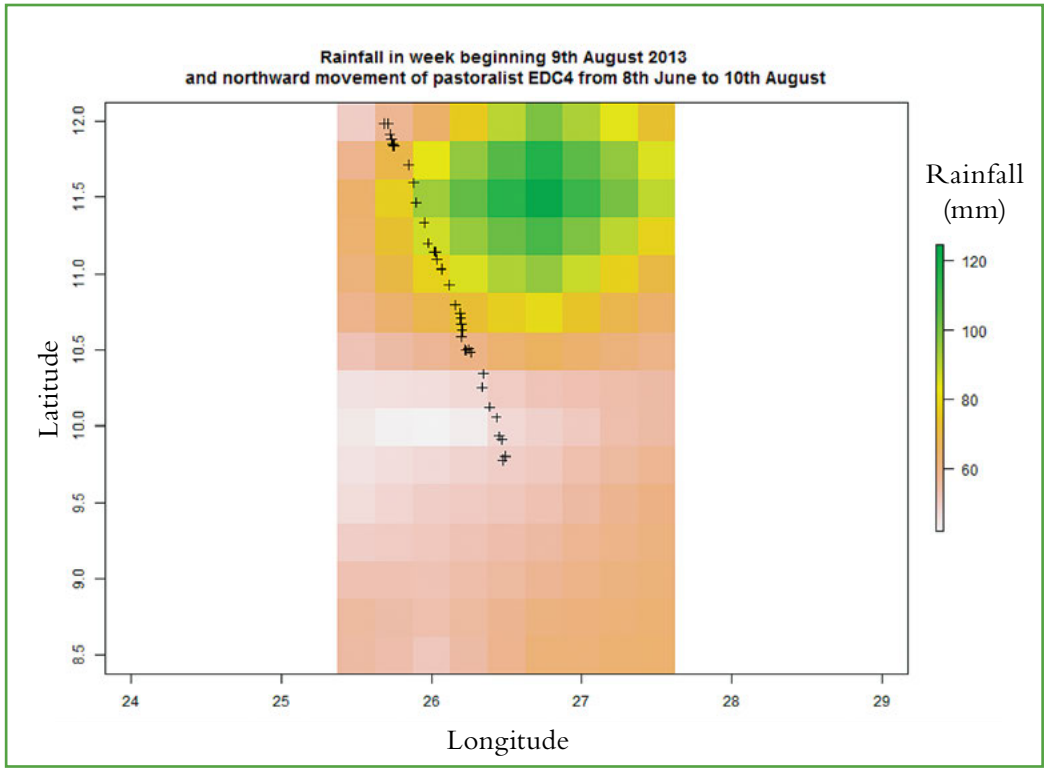


Figure 10d. Northward movement of Pastoralist 4 Cattle from June 8 to August 10, 2013 and total weekly rainfall beginning August 9, 2013.



It would seem that the two monitored cattle herds, Pastoralist 1 and 4, are both generally following the pattern of the rains as they intensify and shift northward. However, there is no obvious correlation between these movements and particular rainfall events along their routes, as shown in Figures 10c and d. Notably, Pastoralist 4 Cattle returns south in mid-August after two large rainfall events to his north (Figure 10b). At the same time, Pastoralist 1 Cattle turns west (Figure 10c), despite the fact that the heaviest rains of the season have just fallen to the east and north of his route.

These deviations from their usual route were related to the eruption of tribal conflict between the Ma'aliyya and Southern Rizeigat, and the violent clashes that erupted on August 9, 2013 in Adila and Abu Karinka localities (Young et al. 2013).

It is also clear that these two herds are in this season consistently moving **away** from the heavier rainfall areas that they occupied in the dry season (see Figures 11 and 12).

Figure 11. The cumulative northward movement in 2013 of Pastoralist 1 Cattle and the daily precipitation at the start and destination locations.

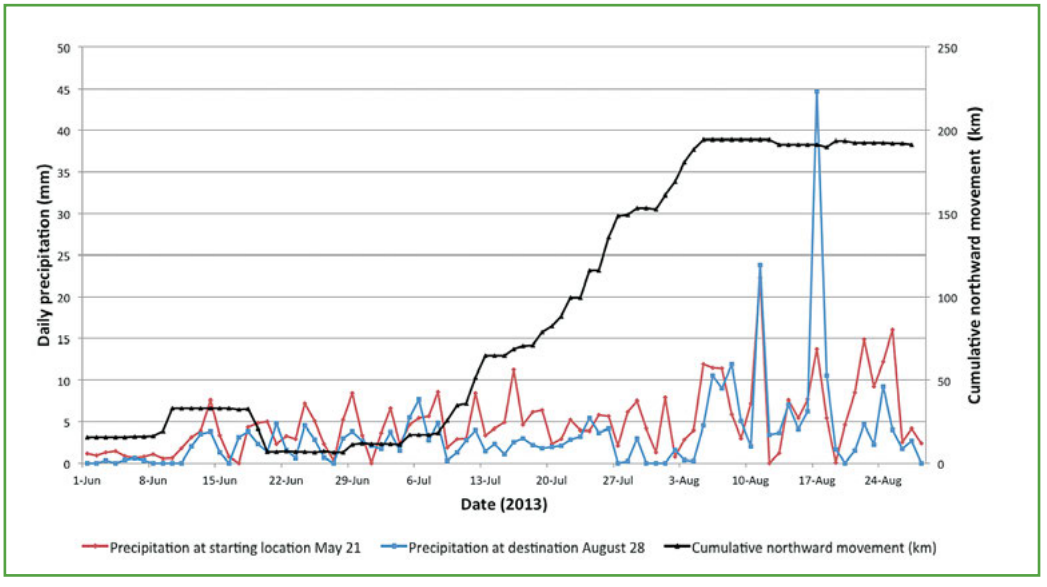
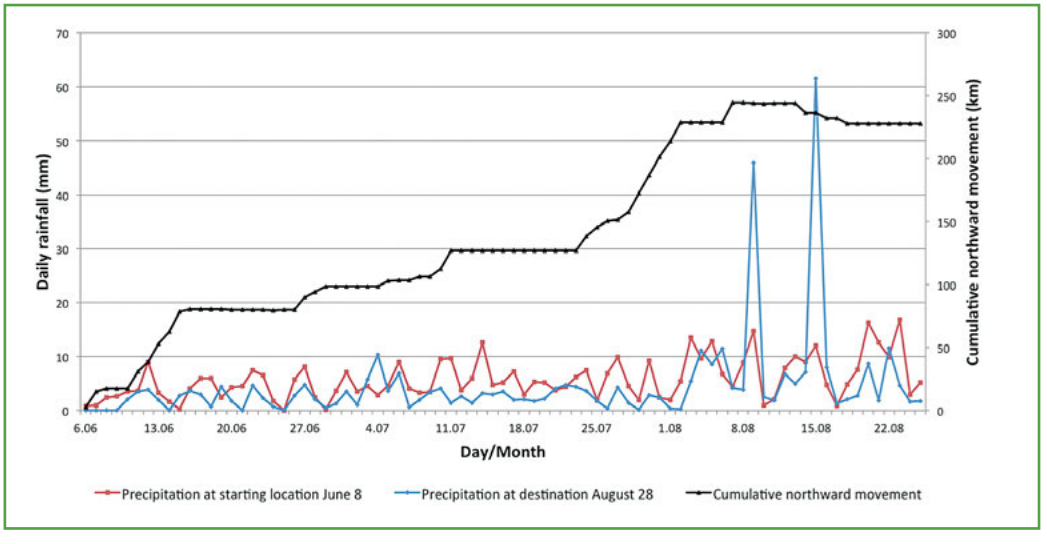


Figure 12. The cumulative northward movement in 2013 of Pastoralist 4 Cattle and the daily precipitation at the start and destination locations.



In summary, our analysis suggests that "chasing the rains" is a misleading depiction of how pastoral herds in East Darfur respond to precipitation in the wet season. Early in the rains (*rushash*), the herds may indeed move towards areas of high average annual precipitation in the study area, but as the rains progress, they turn around and head in the opposite direction, towards areas with the lowest mean annual rainfall. While our sample is small and our conclusions are tentative, we find no indication in our data that pastoralists pursue individual rainfall events. In 2013, considerations such as insecurity outweighed the temptation to exploit unusual levels of precipitation. More generally, the monsoonal rainfall regime in this region of Sudan may encourage pastoralists to respond to advancing or retreating storm fronts, rather than individual storms.

Forage—quantity versus quality

The objective of this section of our analysis is to assess the role of regional differences in forage quantity and quality in sustaining the East Darfur migratory system. Our data on forage quality is based on laboratory analyses of the nutritive value of the plant species and plant assemblages that occur in different regions of East Darfur (HTS 1974a, b; HTS 1975a, b). Our estimates of plant biomass employ a remote sensing measure of greenness, NDVI, commonly used as an indicator of the amount and timing of plant growth. The procedures used to analyze NDVI are discussed in the Methods section of this report.

Common sense suggests that migratory livestock should move, if possible, to the places where they can find the most food. This is, however, not necessarily the case. Given the way plants grow, there is frequently an inverse relationship between plant productivity (the amount of plant growth) and the feed value of that productivity. Plants that produce large quantities of plant material often produce poor-quality feed, especially in the Sudan-Sahel region (Breman and de Wit 1983).

This trade-off between feed quantity and quality presents migratory ungulates and their herders with a dilemma. They can go to places that contain the most feed or to places that produce the best feed, but they frequently cannot meet all their requirements in one place. Pastoralists often reconcile this dilemma by moving to areas with large amounts of low-quality feed in seasons when feed is scarce and their primary concern is to find enough for the animals to eat. They then move to areas with high-quality feed in seasons when plant material is abundant, and they can afford to be selective (Senft et al. 1987; Behnke et al. 2011). Migratory systems for both livestock and wild ungulates emerge when the places that produce the best-quality forage during the growing season (when feed is plentiful) are distant from the places that reliably produce large quantities of feed when plants are dormant (and feed is scarce). Plants are dormant in the semi-arid tropics during the dry season, and, in its most rudimentary form, pastoral migration in these environments consists of a seasonal oscillation between wet and dry season grazing areas. This is the movement pattern that we saw in East Darfur.

Figure 13 shows the seasonal fluctuations in rainfall in East Darfur from 2013 to 2015. The fluctuations show that the 2013 and 2015 rains were delayed, while those of 2015 appear below average. Figure 14 uses changes in regional NDVI values to identify the seasonal pattern of plant growth in East Darfur. Figure 14 suggests that plant growth, and hence the likely availability of green forage for livestock to eat, was highly variable in 2013–15.

Figure 13. Seasonal fluctuations in monthly rainfall in East Darfur for 2013, 2014, and up to August 2015.

(averaged over five of the six pastoralist zones)

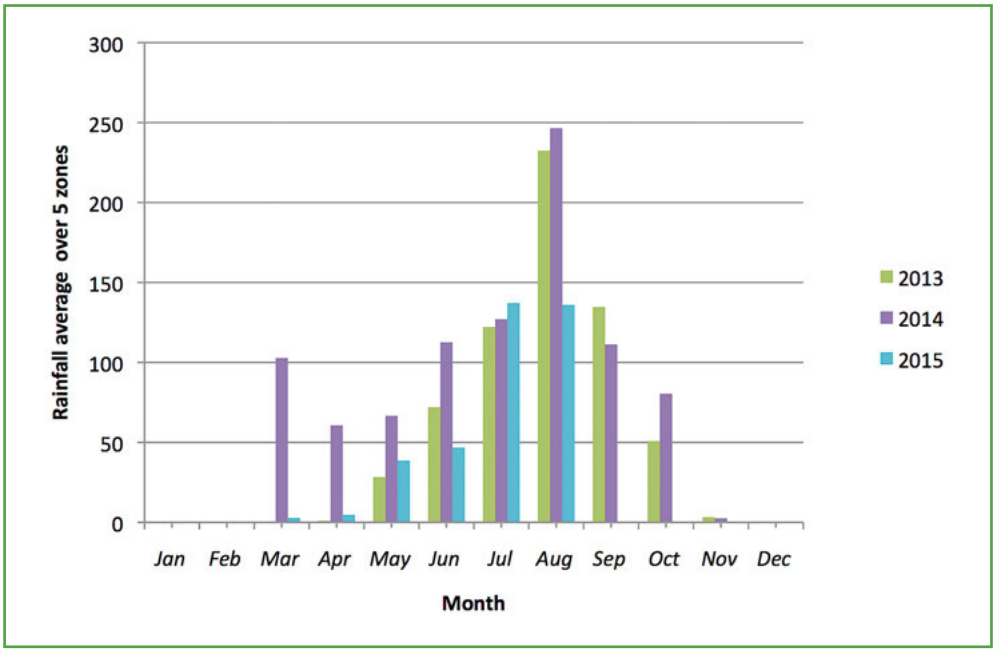


Figure 14. Seasonal fluctuations in NDVI and rainfall in eastern Darfur for 2013.

(monthly mean NDVI and rainfall mean for five of the six pastoral zones)

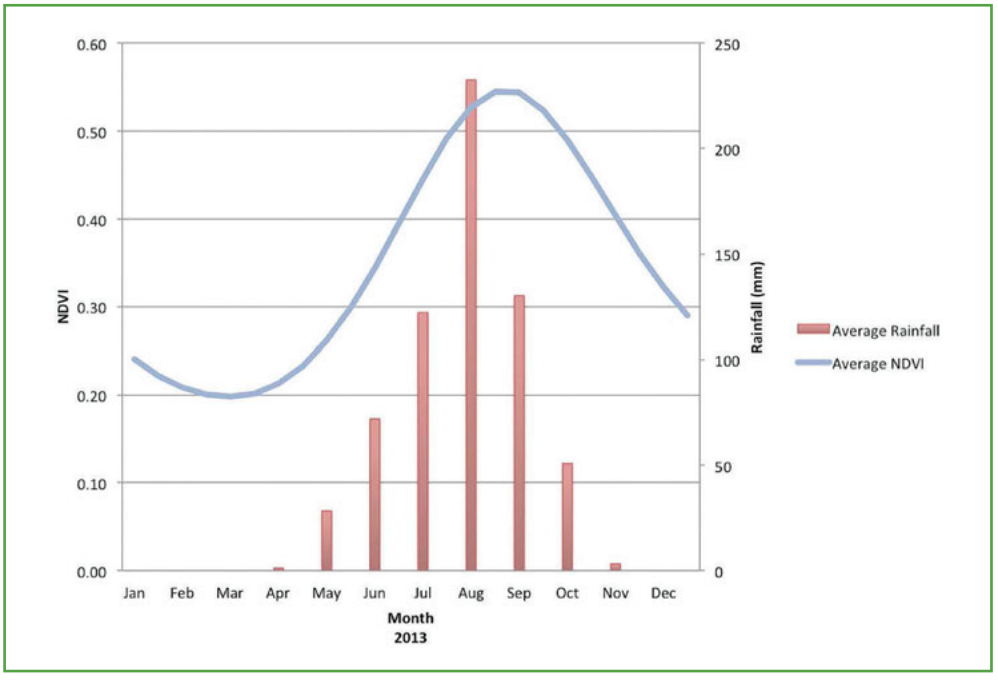


Figure 15 presents NDVI values across East Darfur for 14 years, 2001–14; the data summarized here show that, despite annual variations in the distribution and amount of rainfall, the oscillation between periods of plant growth and dormancy documented is a regular seasonal occurrence in East Darfur.

Figure 15. Seasonal fluctuations in mean NDVI across the five of the six different pastoral zones in eastern Darfur, 2001–2014.

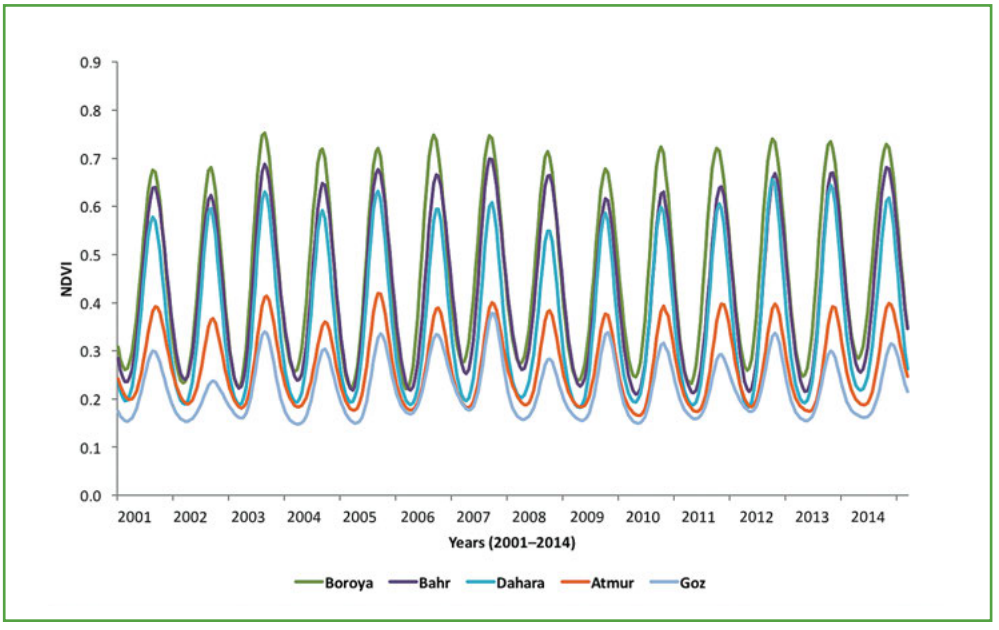
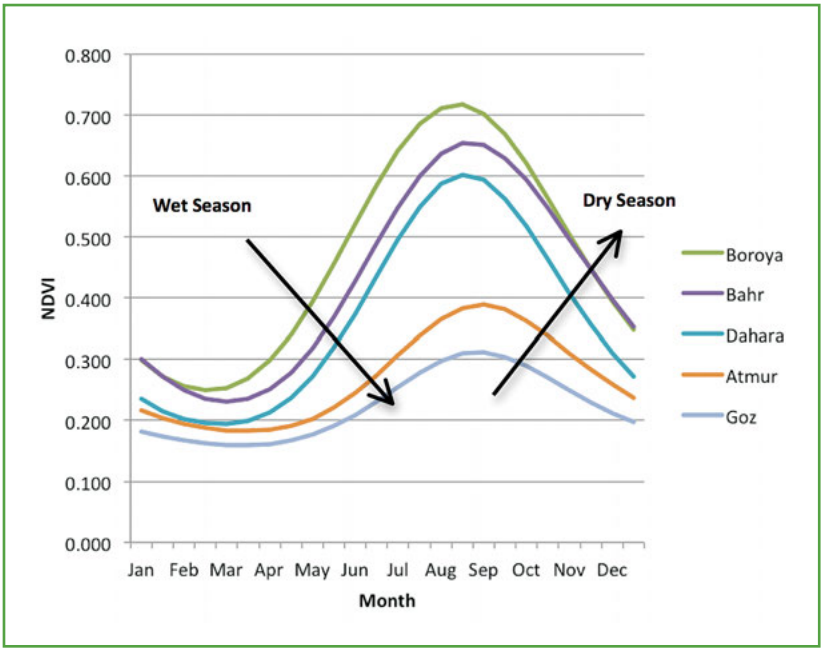


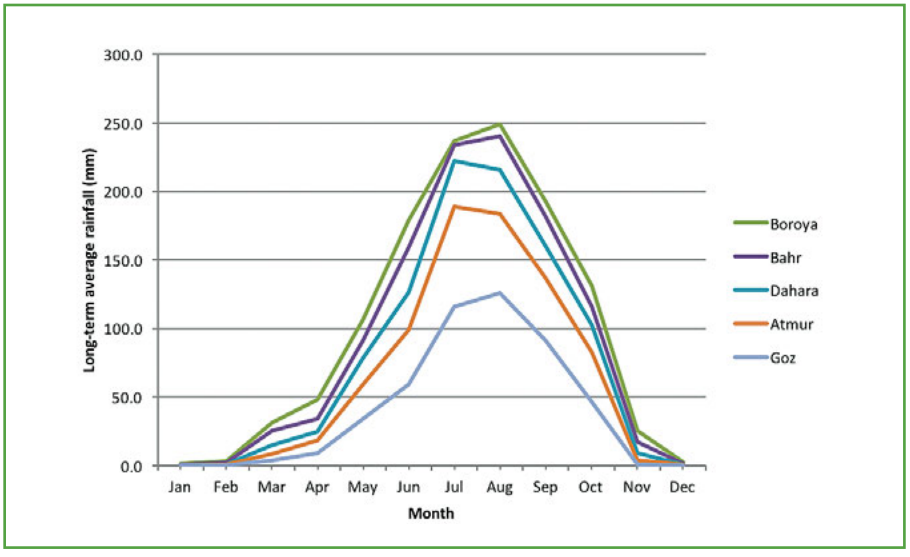
Figure 16a. Long-term mean biweekly NDVI for each of the five pastoral zones in eastern Darfur from 2001 to 2014.



Note: The arrows indicate the general direction of herd movements in the wet and dry seasons.

In addition to seasonal fluctuations in NDVI, there are differences in mean NDVI values between different environments in East Darfur. Figure 5a mapped the location of five 20 x 20 km sites used in this study to estimate NDVI values in five of the six pastoral zones of East Darfur. Figure 16a shows the mean biweekly NDVI, and 16b shows mean monthly rainfall for these five pastoral zones over the course of a year.

Figure 16b. Long-term mean monthly rainfall for five pastoral zones, 1979 to 2014.



The timing of the pulse of vegetative growth, from April-May through to August–September, is roughly similar across all the pastoral zones in the State, but the mean NDVI values for zones differ significantly from one another. In virtually all seasons, both mean NDVI (and presumed vegetation biomass) and rainfall are higher in the south of the study area, and progressively decline as one moves north (Figures 16a, b). As herds migrate north in the rainy season, they therefore move against the gradient of plant productivity. They move from areas of relatively high to low rainfall and plant biomass (arrow indicating wet season movement in Figure 16a). Conversely, when herds move south in the dry season, they move with the productivity gradient into areas of increasingly high plant biomass (arrow indicating dry season movement in Figure 16a).

Forage quality in East Darfur is inversely correlated with plant growth and NDVI. Where NDVI is high, quality is low, and vice versa. HTS laboratory analyses from the 1970s provide information on carbohydrate and crude protein production in three of the five pastoral zones of concern, the Atmur, Dahara, and Bahr. With respect to both of these measures of forage value, forages in the north are more nutritious. The grazing in the Atmur is of better quality than that of the Dahara, which in turn is better than that of the Bahr. The mean crude protein content of pasture samples from the Atmur (9.2 percent) was, for example, about three times greater than the mean for the Dahara (3.1 percent) (HTS 1975b). The HTS data are old and do not cover our study site completely, but these findings are corroborated by authoritative studies conducted elsewhere in the Sahel and East Africa (Breman and de Wit 1983; Fryxell, Wilmshurst, and Sinclair 2004; Holdo, Holt, and Fryxell 2009; Owen-Smith and Novellie 1982; Georgiadis and McNaughton 1990). For the purposes of this analysis, we will assume that the trends found in the HTS data hold true generally across the study site and that northern zones, though they produce relatively little, produce forage of higher quality (i.e., higher protein) than do southern zones.

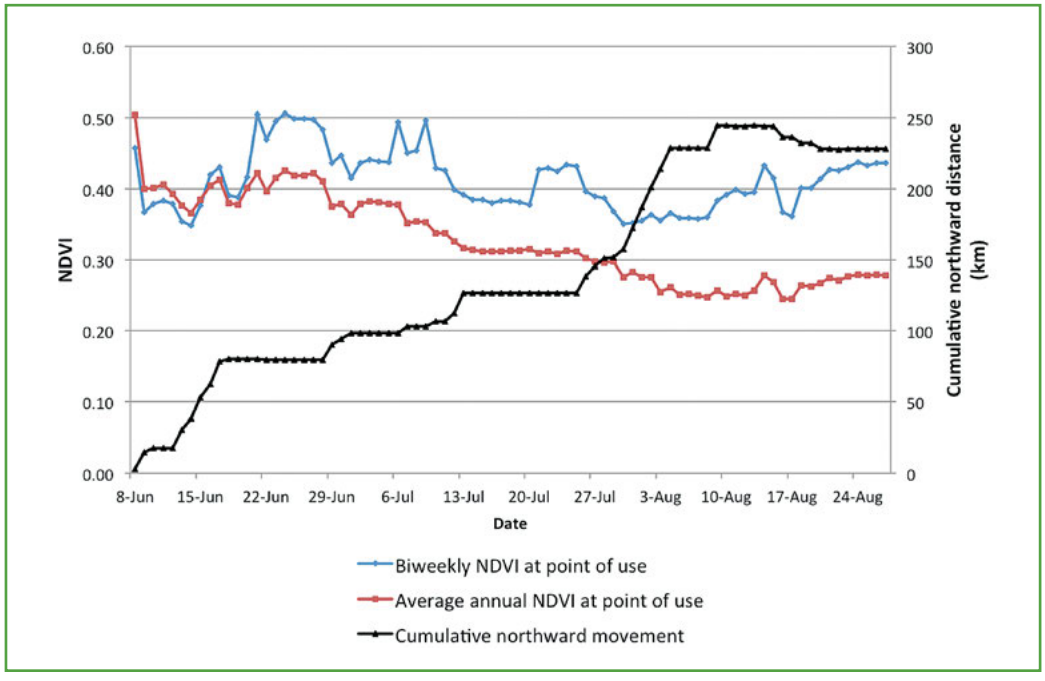
The following two figures examine the impact of these botanical regularities on the forage available to individual herds at different points in their migratory cycles. In Figure 17, the black line charts the cumulative northward movement of Pastoralist 4 Cattle in the wet season, early June to late August, of 2013. In this year, Pastoralist 4 Cattle moved steadily northward from June to mid-August, then moved a short distance south for several days in the third week of August. Recording then stopped on August 27 (Figure 10b). The red line in Figure 17 marks the mean annual NDVI along this track. As Pastoralist 4 Cattle moved north, he

moved progressively into areas of lower NDVI, i.e., into areas of less plant growth and diminished total biomass production (Figure 17 and 16a) but, on the whole, better quality forage. Finally, the blue line of the graph in Figure 17 charts the NDVI in the areas occupied by Pastoralist 4 Cattle at the time they were occupied. While there are fluctuations in this value, there is no overall trend from the beginning to the end of the northward migration. It would seem that Pastoralist 4 Cattle is moving north on a schedule that permits him to maintain a constant quantity of forage for his herd, despite moving into dryer areas where plant growth is increasingly restricted. He is able to do this by occupying the sparsely vegetated northern pastures when green plant biomass is most abundant, from approximately August 5 to August 21 (when the record terminates). The NDVI for the area occupied by Pastoralist 4 Cattle is virtually the same at the maximum NDVI for that area over the entire year. Pastoralist 4 Cattle is cropping the northern pastures at their seasonal peak, both in terms of the volume of forage produced and the nutritional quality of that forage.

At this time of the year, when forage is plentiful, getting enough for the animals to eat is not a limiting factor, and pastoralists are free to seek the best-quality forage available. With the coming of the dry season and restricted feed availability, however, concern shifts from optimizing feed quality to simply finding enough to maintain the herd through the dry season. This can best be done by moving back south to areas of higher rainfall and higher plant biomass.

We next pick up the story in the second study, during the latter phase of the dry season at the opposite end of the migratory cycle, when herds are back in the Bahr waiting for the new rains to break. Figure 18 examines the movement of Pastoralist 2 Cattle into South Sudan at this time. As in the previous figure, the black line charts cumulative distance moved, this time to the south. Pastoralist 2 Cattle roamed around in one small area of the Bahr for nearly 100 days, from February 8 to May 16, 2015. Then, after several weeks of rain, Pastoralist 2 moved rapidly south into a new pastoral zone, the Boroya, in the third week of May. The red and blue lines in the graph identify what the pastoralist achieved with this move. Following the general pattern, by moving south Pastoralist 2 Cattle moved into a zone of higher annual rainfall, higher mean annual NDVI, and, we assume, higher levels of forage availability. Especially since lack of stock

Figure 17. Cumulative northward movement of Pastoralist 4 Cattle and annual and biweekly NDVI for locations occupied by cattle at time of actual use.



water had prevented occupation of this area earlier in the dry season, Pastoralist 2 Cattle could expect to find plentiful dry standing hay from the previous rainy season and more browse than in the heavily grazed Bahr zone, which he had just vacated. More dramatic, however, is the jump in NDVI values when Pastoralist 2 Cattle entered the Boroya, following several weeks of strong rains in the area. By moving, this herder located an early source of fresh grazing at the end of the dry season, which is the worst feed supply bottleneck in the annual cycle. As the storm front moved north in 2015, it took five to seven weeks for a flush of new vegetation comparable to that in the Boroya to reach the pastoral camping areas that he had occupied earlier in the dry season (Figure 19).

By chasing after fresh grass rather than waiting for it to come to him, the pastoralist had located 35–50 days of fresh, high-quality grazing in the worst season of the year, all for a trek of seven days. It is the larger herds that are prone to making the Boroya-Butha migration in *rushash*. This is one of the reasons these herds have livestock in good condition to sell as early as July—two months after the end of the dry season—when they pass by northern livestock markets on their way to their wet season pastures. Clearly, in this instance, mobility pays.

Figure 18. Cumulative southward movement of Pastoralist 2 Cattle in 2015, mean annual NDVI for locations occupied by cattle, and biweekly NDVI for these locations at time of use.

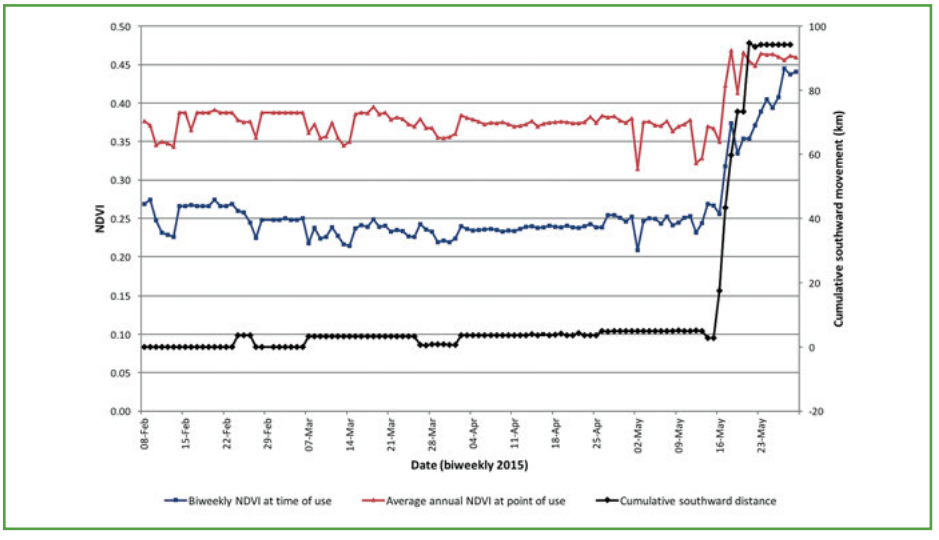
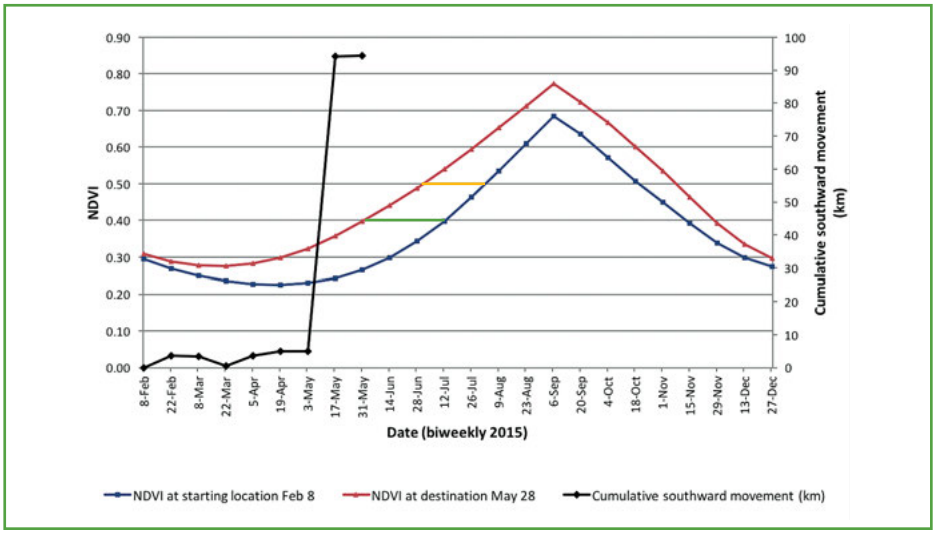


Figure 19. Cumulative southward movement of Pastoralist 2 Cattle in 2015 and annual NDVI curves at starting location on February 8 and destination location on May 28, 2015.



The green line in Figure 19 refers to days of fresh grazing gained by cattle moving south to a location with an NDVI of 0.4, or yellow line a location with an NDVI OF 0.5.

Plant growth and forage quality

The previous section examined spatial gradients in forage quality and quantity that were caused by regional variations in soils and climate in East Darfur. In this section, we complicate this static analysis by adding a temporal dimension, the timing of plant growth, maturation, and senescence. For the migratory livestock producer, managing simultaneous changes in both time and space is the crux of the matter. The herder must be in the right place, certainly, but also at the right time.

As herbaceous plants mature and get bigger, their value as feed generally declines. This decline is caused by the dilution of nutritionally valuable cell-soluble materials (such as protein and starch) as the plant grows and by the build-up of structural materials (cellulose, silica, and lignin) that ruminants find difficult to digest. Ruminants are particularly sensitive to these dietary changes, because their intake of new feed is limited by the speed at which they can digest and defecate what they have already eaten. Furthermore, their digestion slows down as the quality of their intake declines and the bacteria in their rumen work less efficiently. Small changes in diet quality therefore produce disproportionate changes in animal weight gain and growth, a process of amplification that has been termed the multiplier effect (White 1983). With cattle, for instance, a modest increase in forage digestibility from 50 percent to 55 percent produces an estimated 32 percent increase in the amount of energy digested per day. This increases the amount of energy available to the animal above maintenance requirements by almost 200 percent and produces a 100 percent increase in weight gain (Blaxter and Wainman 1961; Malechek 1984; Van Dyne et al. 1980).

But these processes can also work to the animals' disadvantage when feed quality is poor. At the opposite extreme of the nutritional continuum, ruminants can starve to death standing in abundant grass that is so low in nitrogen that it will not keep the bacteria in the rumen alive and hence cannot be digested. Ruminant livestock owners therefore have strong incentives to select an optimal diet for their animals. Ideally, what graziers require is tender green growth that is young enough to concentrate nutrients but old and big enough that rates of consumption are not constrained by insufficient supply.

Figure 20 gives a visual impression of the rate of change in NDVI in the five pastoral zones in East Darfur. The rising curves to the far right and left of the diagram indicate plant green-up and growth following the onset of the rains. The falling curves to the right of the chart indicate plant maturation followed by the transition from green to dry vegetation. Table 3 summarizes some of the numerical data illustrated in Figure 20.

Figure 20. Rate and direction of change in NDVI, by pastoral zone (2001–2014 long term average).

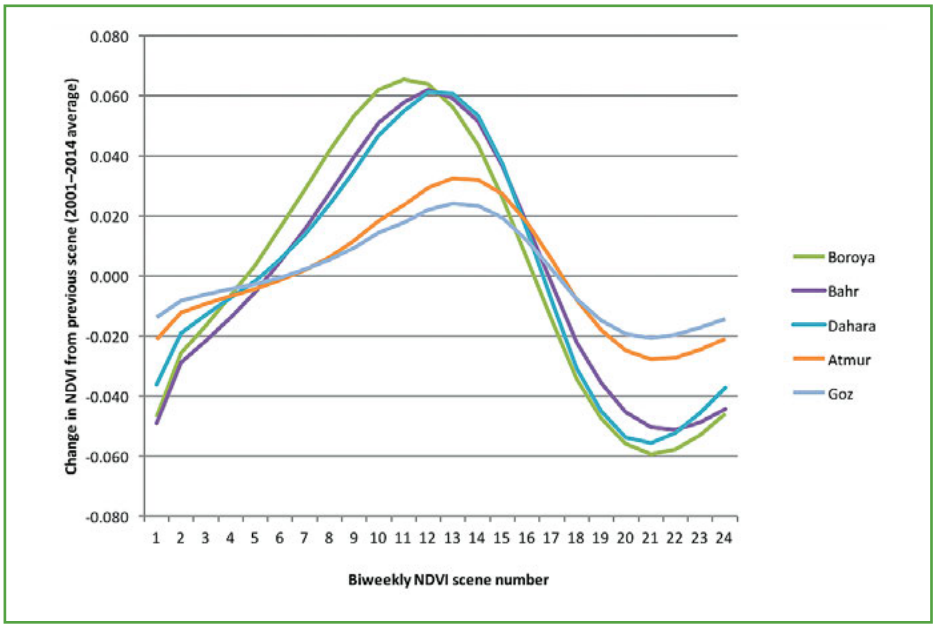


Table 3. Mean green-up and die-back dates: 2001–2014

Pastoral zone	Mean date of maximum NDVI	CV of date of maximum NDVI	Date of maximum rate of negative NDVI change	Date of maximum rate of positive NDVI change
Goz	Late Aug.	5.3	Early Nov.	Early July
Atmur	Late Aug.	4.0	Early Nov.	Early July
Dahara	Late Aug.	3.7	Early Nov.	Late June
Bahr	Late Aug.	5.0	Late Nov.	Late June
Boroya	Early Aug.	3.5	Early Nov.	Early June

Figure 20 and Table 3 are based on biweekly NDVI readings, and the dates are therefore approximate. The overall impression, however, is one of uniformity in the timing of seasonal change in vegetation across the entire study area. Irrespective of the pastoral zone, the amount of green plant material peaks sometime in August and declines most rapidly in all zones in November. What does vary by zone is the reliability of these dates from year to year; the inter-annual coefficient of variation (a measure of variability) is highest where the mean annual rainfall levels are the lowest, in the north. There is also some variation in the dates when plants are growing at their fastest rates in the different zones, but only a month separates the far north from the far south, with the rate of plant growth (date of maximum rate of positive NDVI change) peaking first in the south and moving north in tandem with the advancing rains. This finding suggests that herders may have some limited ability during their northward rainy season migration to exploit the slightly different dates at which plants develop in the different pastoral zones.

During their southward movements at the end of the rainy season, herds have little such capacity to exploit zonal differences. Across all pastoral zones, plant growth peaks in August and green biomass declines at its fastest rate in November (Table 3). As they senesce and dry, the bulk of the plants across the study site are on the same schedule, and moving the herds from zone to zone affords little advantage.

Faced with the simultaneous disappearance of green matter in the dry season across all pastoral zones, pastoralists use two additional techniques to prolong the time their livestock have access to green forage. One of these techniques involves the exploitation of environmental heterogeneity, but on a reduced spatial scale, utilizing variations in micro-topography within pastoral zones, particularly the Dahara and, to a lesser extent, the Atmur. The Dahara and Atmur are the remains of the water courses and floodplains of an extinct river system that once drained the area around Nyala into the Bahr al Arab, and now consists of a complex of very broad (up to 150 m) meandering channels and ox-bows, large lakes, and smaller clay depressions, that are separated by interfluve areas (HTS 1975a). Reflecting slight changes in elevation, the soils of both the Dahara and the Atmur are variable, with hard or sandy textured soils on the high ground and clay in the bottom lands. Herds tend to stay on the high ground on their journey north in *kharif* (*munshaq*, the process of moving north). These elevated areas are attractive, because grass appears quickly after the rains (Atmur soils are a mixture of sand and clay), and the elevated areas provide firm footing for the livestock (on *garduud/naga*, non-cracking clays with a hard sub-soil and a sealed surface that reduces water infiltration) at a time when it is impossible to move through low-lying areas of heavy clay (*butha*). Conversely, on their return south, the herds and flocks follow a low-land route on the heavy clays (*butha*), which are now passible and contain the best forage and most abundant water (see Figure 21, photo of cattle grazing in standing water).

> Although they occupy relatively small areas of cracking clay soil within the [Dahara] and Bahr Land Systems, the [periodically flooded depressions] produce two to three times as much dry matter as the surrounding communities and their carbohydrate and protein production remain high much later in the dry season. (HTS 1975a, 62)

Unfortunately, we have no GPS tracking data to document the routes taken by herds as they return south in the early dry season. If we are eventually able to collect this data, we would expect to observe subtle differences in northward or southward herd movements over the same landscape, with livestock moving quickly north on high ground in the rains, but slowly south, lingering in low areas on the return journey.

The second way that pastoralists in East Darfur extend their access to green forage is through the use of fire to "reset" the plant maturation process. In the semi-arid tropics, this practice is typically used by pastoralists in areas where rainfall is high and the grass is too mature or coarse for livestock to consume. This typically occurs when they return to the Bahr in the dry season after being absent in the rainy season. In East Darfur, the Dahara, Bahr, and Boroya are all burned in the dry season, but fire has an especially significant effect on feed supply in the Bahr.

Burning in the Bahr is important because it produces green forage, which is scarce in the dry season. Dry season regrowth is possible because grasses in burned areas of the Bahr draw upon residual moisture in the heavy clay soils typical of the zone. Burning the mature vegetation also removes dead plant material and exposes green growth to grazing:

Burning is fairly widespread, with an estimated 60 per cent of dry matter destroyed before June. The fires tend to move through the dry upper parts of plants, leaving the lower stalks exposed, and, since the soils of the Bahr Land System remain moist much later than in other areas, the lower stalks still have a high nutritive value at the time of burning. (HTS 1975a, 94)

Sheep herds profit from the regrowth following a fire, which also kills ticks. Cattle herders, on the other hand, would prefer there were no fires because cattle, unlike sheep, have difficulty eating the short grass that appears after a fire, and are better off eating standing hay in unburned areas. The conflicting grazing requirements of cattle and sheep are apparent in the grazing of *fawa*, which are large, flat depressions with very tall grass and no trees in the Bahr area. The grasses of the *fawa* must be burned before sheep can eat them, but cattle can graze them without burning.

In sum, pastoralists in East Darfur extend the availability of green forage by exploiting asynchronous cycles of plant growth and die-back. In the rains, this variability can be found on a zonal, spatial scale, and herds move from zone to zone to optimize their access to fresh plant material. In the early dry season, pastoralists pursue spatial heterogeneity on a smaller scale by exploiting microvariations in topography, especially in the Dahara. Finally, in the dry season in the Bahr, pastoralists create heterogeneity by setting fires that "reset" the developmental clock by stimulating out-of-season plant growth in low-lying areas.

Dry season grazing and water availability

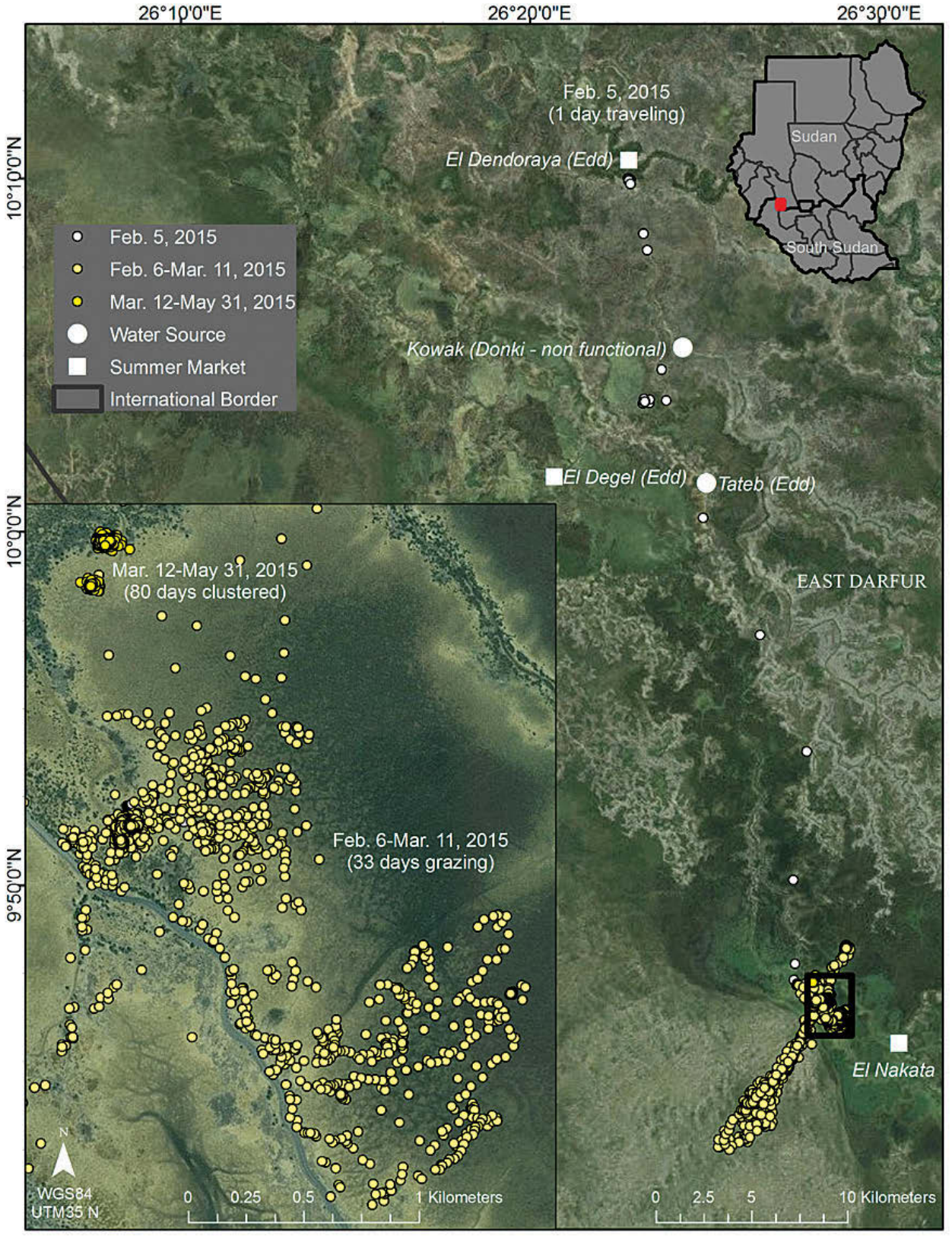
During the dry season, all the livelihood-related activities of pastoralists, including their camping areas (*farig*) and seasonal markets, are concentrated alongside water sources. As the dry season progresses and the water recedes, the pastoralists frequently change their camping sites to be closer to the water. Figure 21 shows the clustering of a sheep herd in the 2015 dry season around the Bahr el Arab River.

The same pattern applies to the location of dry season or seasonal markets. The location of the market is moved two to three times to ensure water sources are nearby. The market reaches its final location at the peak of the dry season adjacent to the most reliable water sources. An understanding of water availability and distribution is crucial for the planning and management of livestock herds and for development planning.

Types of water sources and seasonal use

Water sources used by pastoralist livestock are either naturally occurring, such as rivers, lakes, ponds, surface pools (*ragaba/rugab* (pl.)), and ponds in dry river beds (*dahal/duhuul* (pl.)) or man-made sources, including shallow hand-dug wells (*edd/edad* (pl.)) in the dry part of the river bed, mechanized water yards (*donki/dwanki* (pl.)), and seasonal earth dam reservoirs (*hafir*). In 2013, our group of pastoralists described the water sources they used for watering their animals over the year (about 11 months); these are shown in Figure 22. The pastoralists appear to have a strong preference for natural water sources over man-made ones and a clear seasonal pattern of use. During the middle of the dry season (from

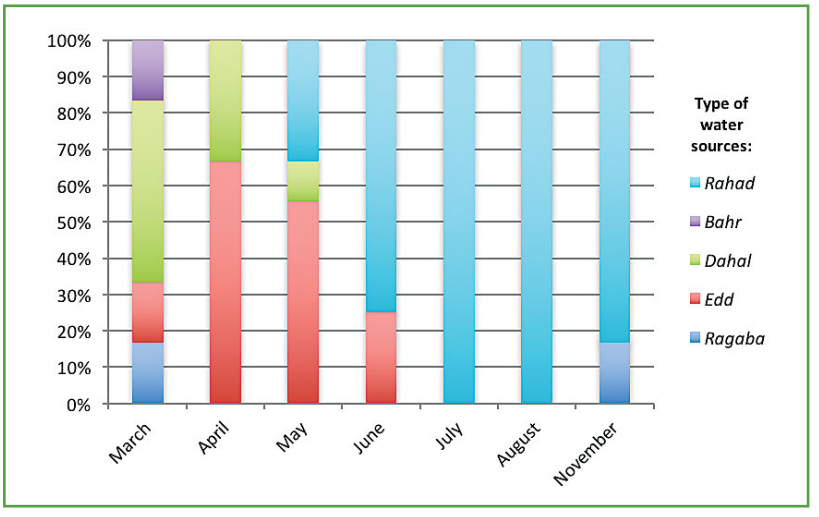
Figure 21. Dry season grazing patterns of Pastoralist 5 Sheep along the Bahr el Arab River, 2015.



March), pastoralists mainly used *dahal* and occasionally used *edd, ragaba*, and the Bahr el Arab River for watering their animals and for their own needs. By the late dry season (April and May), our group of pastoralists showed a preference for *edd*. From May onwards, with the start of the rains and northward movements, pastoralists increasingly used *rahad* until these were the sole water source accessed by the study group pastoralists in July and August, once the rains were fully established.

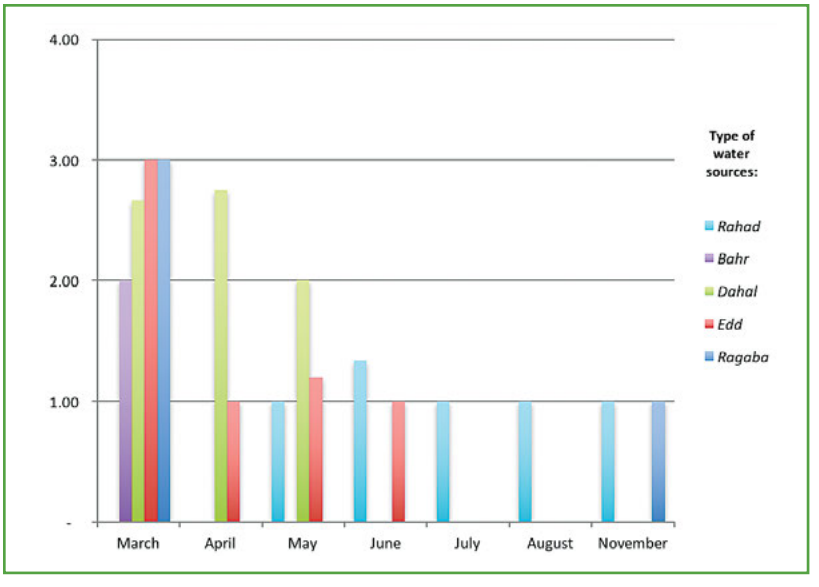
Figure 23 shows that natural water sources in March had an inferior quality compared with natural water sources at other times of year, confirming that water quality as perceived by pastoralists deteriorates in the dry season. Figure 23 also shows that *duhuul* consistently provided inferior-quality water, probably as a result of heavy use and concentrations of livestock around the unprotected pools, overlaid on muddy soil. In April, May, and June, the *edad* (shallow wells) consistently scored a high-quality score, which partly explains the users' preference for this water source. Man-made sources are used generally towards the end of the dry season after the depletion or shrinking of natural standing-water bodies.

Figure 22. Seasonal use of different water sources by cattle pastoralists in East Darfur from March to November 2013.



Note: From March to November 2013, the six herders reported accessing five types of water sources (44 total responses, with no data collected in September and October).

Figure 23. Water quality of different water sources by month as scored by East Darfur pastoralists, 2013.



Note: 1 is highest quality; 4 is poorest quality.

Surprisingly, none of the six herders reported using a *donki*. Currently in East Darfur, water yards are the property of the government, managed by the Water Department. Few *dwanki* are available and are limited to major market places in the Bahr, such as at Dehel Eldabi and, recently, at Elnakata.

The pastoralists reported they are using the system of shallow wells rather than water yards, because water yards are few and often not working. Repairs and maintenance can mean they are closed for weeks. In such situations, watering is a real problem if a pastoralist has no access to an *edd*. There are charges to be paid at the *donki*, whereas access to all-natural water sources is free. There are also charges associated with using a man-made *edd*. Pastoralists must pay for the labor to dig the shallow well and manually extract the water from the well to water animals. All the study group pastoralists reported paying charges associated with using an *edd* for watering their animals.

In contrast to government management of the *donki*, a local committee of pastoralists governs the *edd* system, which includes distribution of new wells allocated to individual users, allowing adequate space or corridors for the passage of people and animals, and giving permission for digging new wells and renovation of old ones. The aim is to distribute the shallow wells and spread the herds so as not to interfere with livestock traffic and provide water for all who need it.

Livestock watering

Normally Rizeigat pastoralists spend from approximately November to May—*shita* (cold dry season) and *seif* (hot dry season)—in the Bahr. The distribution of water sources in the area influences the distances that livestock herds travel from their camp (*farig*) and the time spent in the watering place. Finding suitable watering sources is not a pressing problem in the Bahr. However, with the concentration of large numbers of animals in the area, the choice of where to water has to be made carefully. Herds of different owners may mingle at the water pools. Nevertheless, the local tradition of not allowing livestock to congregate too close to each other is maintained. Instead of watering for one to two hours in *shita* and early *seif*, watering in the late dry season might extend to six to seven hours, especially if the water source is far from the *farig*. However, watering and grazing are associated in many cases, as shown in Figure 24. The water is stagnant with no real current, which allows the growth of water plants such as *Cyperus papyrus, Oryza longistaminata*, and *Echinochloa pyramidalis* (Harrison and Jackson 1958). These plant species represent important fodder sources for livestock, especially for cattle.

Frequency of watering in the dry season

Pastoralists water their livestock (both cattle and sheep) every day until the middle of the dry season, but thereafter the watering regime might change. Those who decide to travel south to the

Figure 24. Grazing cattle near dahal in the vicinity of Um Sagei in the Bahr area

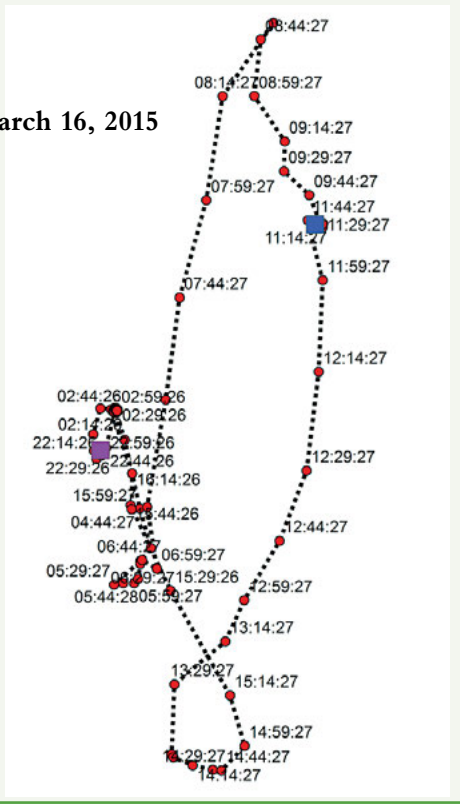
Boroya and Butha continue the daily watering of their livestock, while those who remain in the Bahr reduce their watering frequency to every two to three days. Box 1 shows examples of the dry season daily routine and movements of livestock while they are in the Bahr area. Pastoralists are aware that their animals need more water because the weather is getting hotter. They follow this hard option of reduced watering frequency to minimize the overall cost of watering, as at this time watering is from an *edd* or a *donki*, and both options cost money. Therefore, staying in the Bahr area is an option only for medium to small herd owners. Large herd owners cannot bear such high costs, due to the large number of animals to be watered.

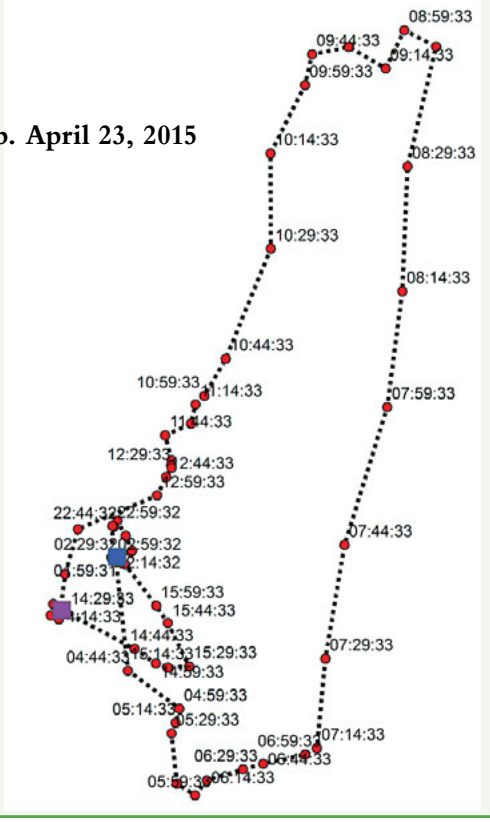
Box 1.

The dry season daily routine and movements of a pastoralist's livestock.

Below are maps showing a pastoralist's daily routine in March and April as captured by GPS records. The interpretation was done together with pastoralists. The first thing that happens is that the calves are released from the calf rope and allowed to nurse, which takes place before milking. Milking takes around one hour. This is the time of the year when milk yield is lowest. Animals often leave the family camping place (*farig*) at around 08:00. The daily herding movement starts in the direction of a water course. Movement to and from watering is associated with grazing. The herd continues to walk and graze slowly until around midday and then rests under shade to avoid the high temperatures for approximately two hours. Around 15:00, the herd starts the second part of their daily grazing and slowly changes direction, heading towards the *farig* so as to reach it around 17:00. Evening milking starts immediately after the arrival of the herd. After milking, the calves are again attached to the calf rope. Generally, the radius of grazing from the *farig* depends on the distance from the water source, ranging from three to four km. The patterns of daily herd movements are the result of combined decision-making by herders and animals. For example, herders decide where to water animals, while animals decide the direction taken towards the *farig* in the evening. Although their daily routine in terms of time (i.e., herding hours) remains almost the same when camping in one place, the distance covered varies from day to day.

Examples of the daily pattern of movement by cattle of Pastoralist 2 Cattle. The purple square is the overnight camp place (*farig*), and the blue square is the midday rest place. Time is in UTC.





Changing patterns of migration: Anticipating problems and dealing with the unexpected

While the seasonal patterns of movement are consistent from year to year, the specific schedule for the movements is flexible, because herders must adapt to the variation in the timing, duration, and intensity of the rains. Furthermore, the timing and speed of livestock movements is influenced by other anticipated and unanticipated challenges and unexpected events.

Pastoralists in eastern Darfur anticipate potential problems when they leave the grazing areas in the south and head north through the farming zone toward their preferred northern rainy season grazing areas. The farming zone starts at the latitude of Totoloto in the south and continues up to about Muhajiriya in the north (a distance of about 80 km), shown in Figure 25. The width of the livestock corridor in this area ranges from about 150 m to 1 km. During the period of cultivation, this part of the livestock corridor is frequently blocked by expanding farmers' fields (see Part Three of this report). Figures 10a, 10b, and 25 illustrate the pattern of livestock mobility for two herds from the end of the dry season in May to the establishment of the rains in August/September 2013. At the beginning of the rains, both herds spent some time grazing in a clustered pattern over a wide area (up to 20 km for Pastoralist 2 Cattle for six to eight weeks, and up to 6 km for Pastoralist 4 Cattle for approximately two weeks). By early July, both herds left the rangeland area and started the journey north, travelling at a steady rate, with occasional stops. Once they reached the farming zone, the cattle herds moved faster so as to avoid problems of crop damage and conflict with local farmers. Table 4 shows the mean daily distance travelled (north or south) by three pastoralist cattle herds in 2013. Overall, the mean daily distance ranges from 1.9 to 2.8 km per day and increases when travelling through the farming zone.

The northward movement of these pastoralist herds was also seriously disrupted by a sudden eruption of inter-tribal conflict and violence between the Southern Rizeigat and the Ma'aliya. Because of the conflict and violence, the pastoralists deviated from their planned journey north (Figures 1, 10a, and 25; also see Part Three) by either abruptly turning west in early August, or returning south. While an obvious move to protect their own security, deviating meant negotiating with local farmers to allow their herds to move away from the conflict zone. Pastoralist herds also had to move independently of each other, so as not to increase the burden on local farms. Thus, while the anticipated problems in the farming zones can be planned for by increasing the daily distance travelled, major inter-tribal conflict is harder to predict and calls for more reactive adaptive responses.

Figure 25. Migration north of Pastoralist 2 Cattle from the end of the dry season to the establishment of the rains in 2013.

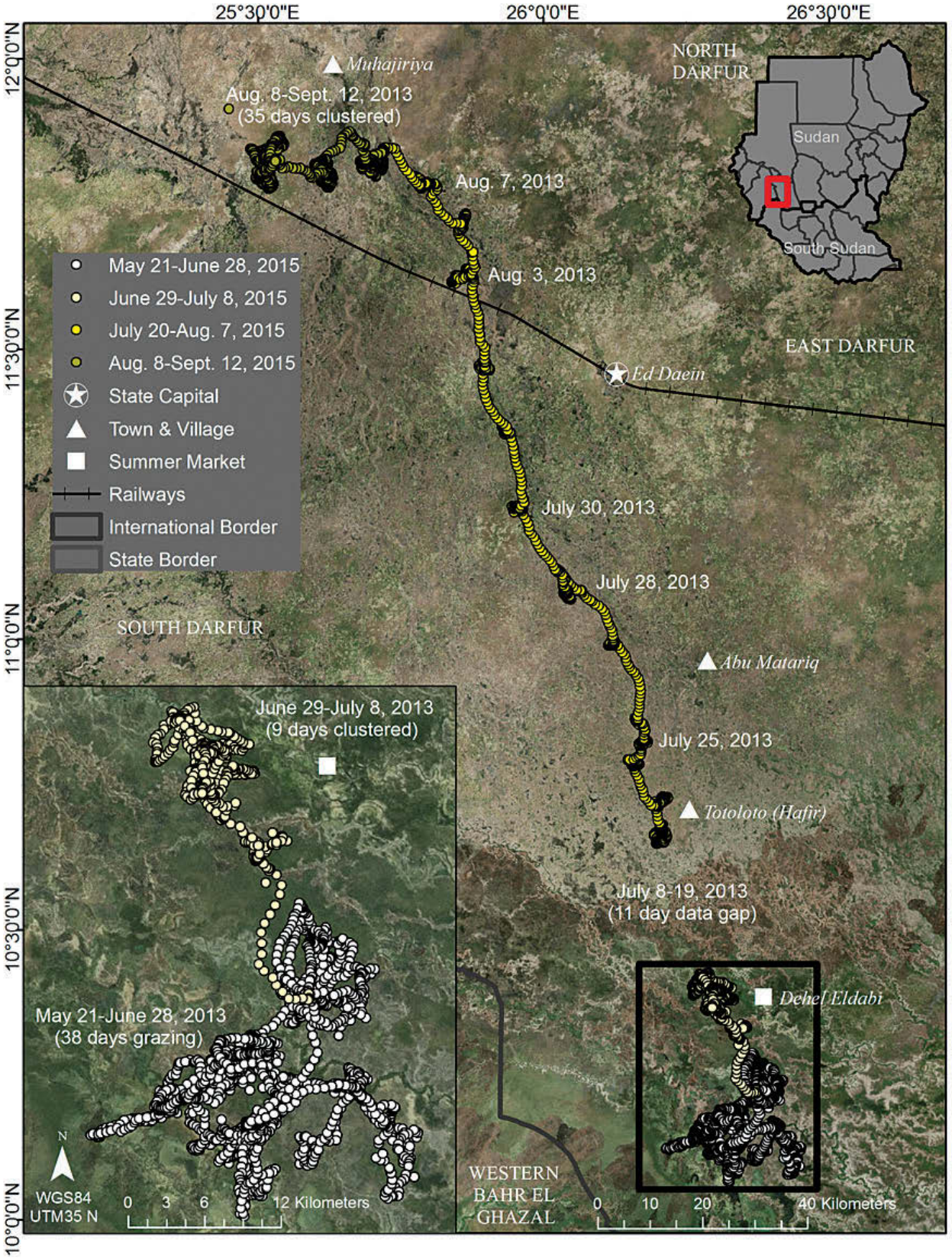


Table 4. Mean daily distance of Pastoralists 1, 2, and 4 Cattle.

Mean daily distance north or south, Pastoralist 1 Cattle, 2013

Location	Dates	Mean (meters)	Number of days
Overall	May 21 to August 28	1,933	99
From Bahr to Totoloto	May 21 to July 11	693	52
After Totoloto (pre-conflict)	July 12 to August 8	5,658	28
Post-conflict	August 9 to August 27	-160	19

Mean daily distance north or south, Pastoralist 2 Cattle, 2013

Location	Dates	Mean (meters)	Number of days
Overall	May 20 to September 12	1,542	104
From Bahr to Totoloto	May 20 to August 3 (no data from July 3 to 19)	2,282	65
After Totoloto (pre-conflict)	August 4 to August 8	4,700	4
Post-conflict	August 9 to September 12	-53	35

Mean daily distance north or south, Pastoralist 4 Cattle, 2013

Location	Dates	Mean (meters)	Number of days
Overall	June 8 to August 28	2,815	81
From Bahr to Totoloto	June 8 to July 7	3,399	29
After Totoloto (pre-conflict)	July 8 to August 9	4,295	34
Post-conflict	August 10 to August 28	-919	18

Note: Mean daily distance is the sum total movement in a northward (+) or southward (-) direction.

Discussion and conclusions: Heterogeneity, risk, and resilience

The husbandry techniques that pastoralists use to anticipate and respond to variability are not immediately obvious, widely understood, or respected. This report relies heavily on remote sensing data to describe pastoral behavior in relation to some of the biophysical factors that are important for livestock production in East Darfur. Our goal is to provide policy makers with an objective account of what mobile pastoralists in Darfur can achieve, how they do it, and what they might need to do it better.

The bulk of our analysis has focussed on the positive incentives for pastoral mobility. Central to our account has been documentation of the myriad ways that migration preserves access to green forage, thereby sustaining levels of livestock nutrition that enhance livestock production and reproduction. We have placed less emphasis on how movement minimizes problems and constraints, but avoiding trouble is equally as important.

For pastoralists, trouble manifests itself differently in different pastoral zones at different times. In the southern pastoral zones, so important to livestock in the early to middle dry season, trouble comes with the rains in the form of flooding and mud that makes movement difficult, followed by outbreaks of flies and mosquitoes.

The feed limitations of the northern grazing areas in the dry season are less dramatic than the flooding of the southern regions, but nonetheless debilitating for livestock. The crude protein content of northern grasses falls off rapidly after reaching maturity (Ismail et al. 2015), with December protein values about half those for September and October (HTS 1975a). Combining consumption by termites and the loss of digestible protein to volatilization, northern pastures ungrazed in September have lost 75 percent of their feed value by the end of the dry season in May. The scarcity of good pasture leads to seasonal mineral deficiencies (Abdelrahman, Kincaid, and Elzubeir 1998) and weight loss among livestock (Dawelbait, Gadalla, and Bushara 2011)) and produces sedentary livestock that are less productive than their migratory counterparts (Wilson and Clarke 1976).

But problems of mud, flood, flies, and feed are only half of the story for migratory producers. The strong point of pastoral mobility is its capacity to turn temporary deficiencies to advantage. The mud and flooding that drive livestock from the southern pastoral zones in the wet season provide the abundance of stock water and forage that attract livestock to these same areas in the dry season. The marked decline in the nutritional value and abundance of northern pastures in the dry season is associated with the intense but brief florescence of these annual pastures in the wet season, when migratory herds graze them. Flooding in the south or the rapid decline in the northern pastures are not problems for migratory herds. As long as the herds can leave when the problems arise, problems can often be transformed into benefits, in another season. Manipulating space and time—where herds are and when they get there—is the essence of mobile strategies for exploiting environmental heterogeneity.

Mobile strategies also provide a means for managing risk associated with extreme rainfall variability. In 2015, the ongoing El Niño climatic event was associated with a delayed start to the rains and below-average rainfall in parts of Sudan (FEWS NET 2015). FEWS NET reported that delayed rains (starting four to six weeks late) and a shorter-than-average growing season adversely affected crop production. East and North Darfur were included in a list of areas where crop production was most impacted by dryness (FEWS NET 2015). Humanitarian concerns have since been raised about farming households in areas where there is no harvest, households that are now dependent on the market to purchase their food.[5] The pastoralists in this study also reported that 2015 was the worst year in their memory. They explained that the late start and lower rainfall than expected in North Darfur hastened their return south from North Darfur to the Bahr. However, their mobile strategies enable them to anticipate potential problems and schedule their movements accordingly. Sometimes they delay the movement north to coincide with greening up or, alternatively, return earlier to the south, as they did in 2015. The early return could have meant significant overcrowding and increased pressures on the Bahr region in the dry season. The option for the Baggara (cattle herders) to move south into the Boroya and Butha in South Sudan relieved some of this pressure. Thus, while the pastoralists were seriously affected by the variable 2015 rainy season, their "escape hatch" to the south ensured their resilience.

The pastoralist system profoundly contrasts with alternative approaches to raising livestock on rangeland. Table 5 summarizes some of the fundamental differences between migratory and fenced systems of rangeland use.

[5] The Integrated Phase Acute Food Insecurity Classification for North Darfur in April 2016 was increased to Phase 3: Crisis (FEWS NET 2015, 2016).

Table 5. Landscape utilization in ranching and pastoral systems

Migratory Pastoralism	Fenced Ranching
Intense episodes of grazing	Moderate but constant grazing pressure
Harvest forage at nutritional optimum	Deferred use of pastures
Seasonal use of pastures	Grazing and resting rotate through the year
Livestock exploit and reinforce landscape heterogeneity	Grazing used to promote uniformity in pasture productivity
Variable stocking rates	Set stocking rates
Fuzzy territorial boundaries	Clearly demarcated properties and paddocks

The principles that underpin ranching systems are widely appreciated. Ranchers aim for homogeneity in landscape use, stable livestock numbers, and a continuous flow of livestock products despite spatial and temporal variability. Ranchers "manage" by controlling, or attempting to control, their environment and by using industrial inputs such as fencing, supplementary feed, or water point development to do so.

Pastoralists, on the other hand, exploit the heterogeneity and seasonality that are inherent in rangeland environments. Rather than attempting to suppress variability, they use it. Many pastoralists also have limited access to industrial inputs that might alter the productivity of their natural resources. In large measure, they "manage" not by manipulating but by anticipating and responding.

Part 2. Pastoralist livelihoods: Social and economic dimensions

Introduction

Part One of this report illustrated the particular way pastoralist livestock in East Darfur move in direct response to a range of biophysical drivers. These include rainfall variability, local landscapes, and soil systems, all of which result in the variable quality and distribution of pasture over space and time. This part of the report examines the social and economic dimensions of current pastoralist livelihood systems in East Darfur. We first review pastoralist livestock marketing and trade strategies. Second, we review the increasing diversification of pastoralist livelihoods to include farming and other economic activities. Finally, we present preliminary findings on the social division of pastoralist roles and responsibilities, pastoralist knowledge of trees and plants used by livestock, and traditional uses of these trees and plants by women.

Economics of pastoralist livestock marketing and trade strategies

Livestock trade and markets

Among the larger-scale pastoralists with more mobile herds, the sale of livestock is highly strategic and follows a clear seasonal pattern, with the goal of investment: improving their herds in terms of both quality and quantity, with some smaller sales to meet food and income needs.

Because they are highly mobile, large herd owners can afford to buy thin but healthy animals during *seif*—the dry season—in crowded areas near water sources, from small herd owners who are not as mobile. If purchased during *seif,* livestock prices are low (because fodder is running out in settled areas) and lower still if one stays away from big markets. Apparently, mobile herders can also purchase animals on route when returning south to the Bahr.

Lean, purchased animals can be expected to fatten up early because the larger, more mobile herders are able to take animals further south to the Boroya with its early *rushash* (onset of rains). The pastoralists also look to purchase younger, smaller, and cheaper breeding stock, as compared to full-sized animals ready for market. By choice, pastoralists never sell healthy female animals unless they are forced to by hardship or extreme reasons.

Come *rushash* (onset of rains) and *deret* (end of rains), the large-scale pastoralists look to sell mature, market-ready stock to the traders in the larger markets located along their migratory route in Ed Daein, Abu Matariq, Abu Gabra, and El Ferdus and towards the northern end of the migration cycle, where prices are better. Irrespective of movement, small herd owners tend to sell what is on hand to meet immediate consumption needs, while richer pastoralists sell selected animals from their larger herds (culling barren but fat cows and oxen, for example) to purchase younger breeding stock. This can involve selling large numbers; for example, someone who has 200 head aged more than six years may decide to sell 100 head but will later replace these with younger animals. Large numbers of oxen may also be sold at any one time.

Sales of sheep broadly follow the same pattern and involve selling older or barren animals and buying younger animals. As one of the pastoralists put it, "if you have a big number, you trade [as an investment], otherwise you sell to meet daily needs."

There are also trading opportunities for pastoralists during migration to South Sudan. The pastoralists in the study gave the impression that marketing in no way constrains movement. Instead, movement provides new opportunities for improved marketing, especially since the most mobile herds tend to be large and already have a commercial advantage.

Diversification of pastoralist livelihoods, including farming and other economic activities

As explained by an East Darfur *omda*, "pastoralists are not all equal in the number of cattle they own. Some have many, others have few, and they have other activities." These other sources of livelihood are wide ranging and can be broadly divided into: i) activities linked to pastoralist livestock production, including trading livestock; ii) farming and cultivation of crops; iii) activities

linked with trade and markets; and iv) hunting, fishing, gathering, and harvesting, and some processing, of natural resources for one's own use or as a source of cash income.

Livelihoods linked with pastoralism include: livestock traders, brokers, and guarantors;[6] well diggers and animal waterers in the Bahr region; and hired herders. These jobs are often a means for individual hired herders to eventually establish their own livestock herd. The men in our study group did not emphasize the processing and sale of livestock products as a livelihood activity. When we asked about livestock products, they said that "settlers" or agro-pastoralists have improved breeds of livestock and establish dairies from which they sell milk and milk products.

Trading activities include small shops and local seasonal trade, through the network of seasonal markets that service the pastoralists' needs when they return to the Bahr in the dry season. Cross-border trade occurs with South Sudan at the end of rains and beginning of the dry season (*deret*), when donkeys transport a range of food products (cereals, oil, beans) and fuel, which is then traded in the south. Generally, donkey traders bring little back on the return journey, although some might bring honey, bamboo, cosmetics, and sometimes logs and cat skins.

Pastoralists make use of a wide range of natural resources. Women and men gather, harvest, and collect natural products, including gum arabic, different types of honey, and a wide range of wild fruits, berries, seeds, and tree products. Women in particular are responsible for food processing, food preservation, tanning, handcrafts, and making cultural artifacts (leather work, traditional tents, marriage items, etc.). There is some fishing in the Bahr area and also hunting for python skins, which are used to make local shoes. Charcoal production and sale and the collection of wood for construction, fencing, and firewood are ubiquitous in Darfur and common in this region also.

Farming—cultivation of crops

Previously among pastoralists ("in the time of our fathers"), farming was seen as an activity only practiced by the poor. However, in recent years, more pastoralists engage in farming. Even those pastoralist households with large herds are practicing farming, which has led to the expansion of cultivated areas, associated cutting of trees, and increased numbers of permanent settlements. The study group of pastoralists attributed this trend to the high cost of living and the increasing need for cash to cover expenses. Agriculture is chosen so as to maintain the herd by not selling animals.

Pastoralists often send two or three family members to farm, including perhaps a son, some wives, children (who attend the *khalwa*, a preschool for teaching the Holy Koran), and older women. This increase in farming and expansion of farming areas occurs at the expense of pasture and trees (Krätli et al. 2013; Sulieman 2013; Osman 2013), and has hindered livestock migration, as farms block the livestock corridors (see Part Three).

The crops mentioned include okra, groundnuts, beans, sorghum, and sesame (but not hibiscus). The study group members prefer millet, but bird damage encourages them to plant sorghum instead and buy their millet in the market (Fitzpatrick and Young 2015).

For large herd owners, the location of the farm has no influence on their migration route or schedule. Sometimes a large herd and its owner will pass by his own farm on the migration north, but this tends to occur by chance and serves no necessary purpose. On the way south to the Bahr, family members with the livestock might drop in to visit those staying on the farm. Sometimes, the most advantageous route for the livestock might by chance take the herd by the farm.

Crop residues

Farming also produces crop residues: grain stalks and harvested bean seed pods for fodder and straw for building. Pastoralists with larger, more mobile herds do not buy crop residues, because their herds have relocated south of the farming area before the harvest is completed. It is usually owners of smaller herds that buy crop residues, which serves as a kind of fodder storage. Herd

[6] Every tribe is said to have their own *dhamin*, or guarantor, who will sign a paper (the guarantee) stating that the animal belongs to the owner or seller. Payment is usually made through the guarantor, and for his services the *dhamin* receives a percentage of the sale price, usually 3.5 percent per head.

owners might "buy" a farm (i.e., rent the crop residues for one year) before leaving a farming area, knowing that this source of feed will be available later in the year when the herd returns. Pastoralists who do this tend to be moving short distances around the farming zone.

Social division of roles and responsibilities

Pastoralist livelihoods in East Darfur are a family affair, and the common practice is to divide the roles and responsibilities according to age and gender. Pastoralists return to their temporary "seasonal" locations in the Bahr area in the dry season (*seif*). Women and children may accompany the migrating herds to these seasonal camps, but they do not make the onward journey across the Boroya to the Butha. Instead, the women stay in the vicinity of the Bahr with the children and the sheep and goat herds. The older men, women, and children often stay in a more permanent residence further north, where they farm and children attend the *khalwa*.

All the pastoralists in our study group were men, and almost all livestock owners and herders are indeed men. There are very few examples of women who own and also trade their own sheep and cattle. A woman may inherit an animal, which is kept by her sons and over time multiplies until she owns a sizeable herd. The herd will still be managed by her sons. Daughters may start with a single hen and through careful management and investment in new stock eventually may be able to establish, for example, a small goat herd that she can manage herself.

Depending on the size of the herds or the size of the family, hired herders or extended family members may be needed to help manage the migrating herds. Hired help is also needed for agriculture, initially during *rushash* with clearing and preparing the land before sowing. If there are no tractors available, someone may be hired to plough. At harvest time, the herd owner may hire people to help, or alternatively households help each other with farming.

Specialist knowledge of pastoralists

Women and men have their own specialist knowledge and skills associated with the different seasons and changing landscapes they occupy. Below are examples of such specialist knowledge taken from the 2013 and 2015 studies.

Pastoralists' knowledge of plants consumed by their livestock

During the first phase of livestock monitoring in 2013, the pastoralists in East Darfur and North Kordofan were interviewed on a regular basis. They reported on: rainfall patterns; the local ecology (soil system); watering of their livestock; the grasses, trees, and shrubs eaten by their animals; livestock health; use of feed supplements or crop residues; and their marketing practices for the reporting period.

The 2013 study built a picture of the different plants (grasses, herbs, shrubs, and trees) eaten by the pastoralist livestock, from the dry season at the start of monitoring to the early dry season in October/November. Over approximately nine months, the pastoralists in East Darfur and North Kordofan identified a total of 77 different plants (trees, shrubs, grasses, and herbs), using their local names. Local rangeland specialists later identified 67 of them by their botanical names (see Annex 2).

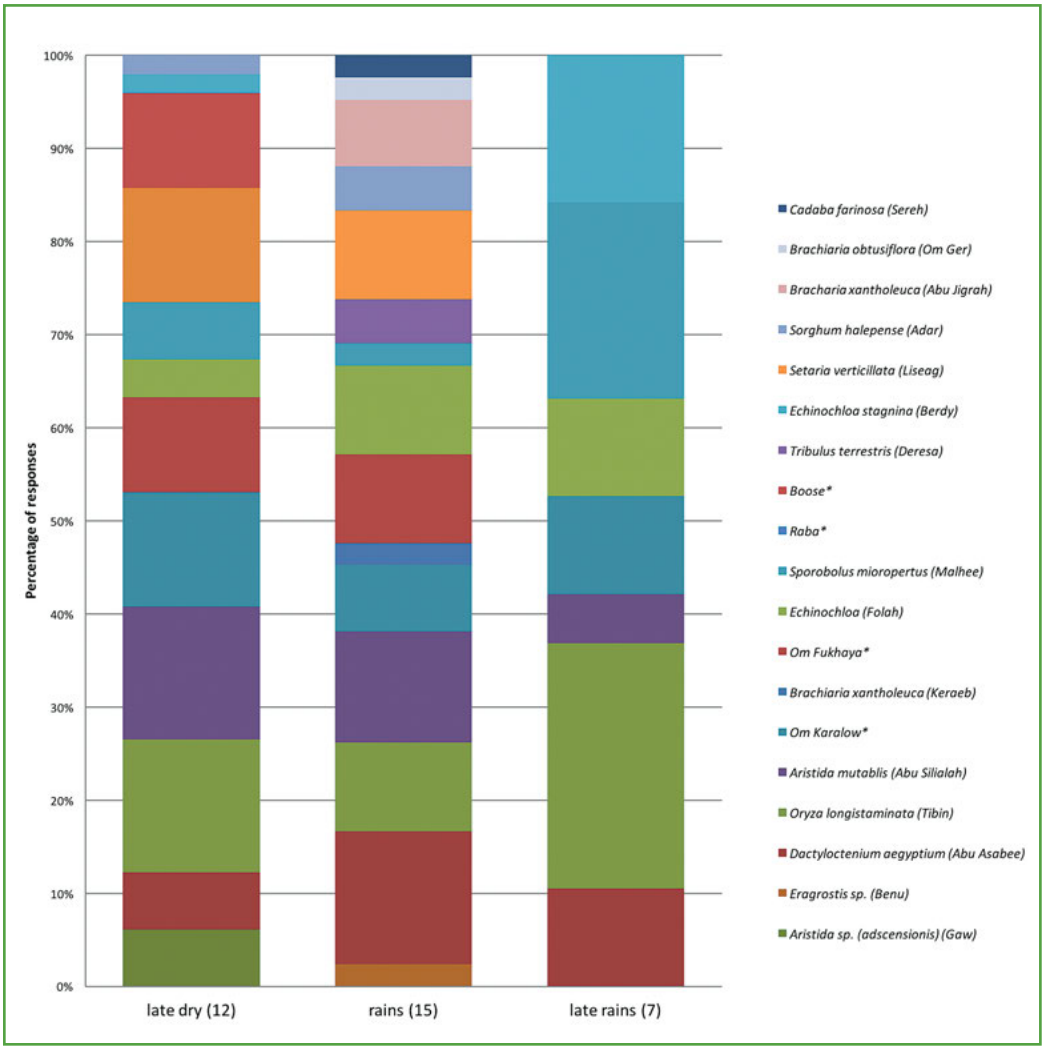
Table 6 lists the three main plants eaten by cattle in East Darfur and the plants eaten by sheep and camels in North Kordofan over the monitoring period. The only overlapping grass species eaten by more than one livestock species in this table is *haskaneet* (*Cenchrus biflorus*). However, among the grasses that were mentioned less frequently, there was some crossover. For example, there were a few reports of all three species (cattle, sheep, and camels) eating *Gaw, Benu*, and *Keraeb* (*Brachiaria xantholeuca*), and cattle and sheep were both reported to be eating *Abu Asabee*. A study of plants that livestock prefer in Kordofan also mentioned these species (Sharawi and Gaiballa 2010).

Table 6. Three most common grasses and herbs consumed by cattle in East Darfur and by camels and sheep in North Kordofan

East Darfur, Cattle	*Tibin (Oryza longistaminata)*	*Abu Silialah (Aristida mutablis)*	*Abu Asabee/ (Dactyloctenium aegyptium) Om Karalow*⋆
North Kordofan, Camel	*Haskaneet (Cenchrus biflorus)*	*Gaw (Aristida sp. (adscensionis))*	*Shara (Indigofera semitrijuga)*
North Kordofan, Sheep	*Shelinee (Zornia diphylla)*	*Benu (Eragrostis sp.)*	*Haskaneet (Cenchrus biflorus)*

Note: Sometimes the local names for particular plant species differed by region, meaning that the same botanical species has several different local names depending on the area.
⋆ Unidentified at the time of writing.

Figure 26. Grasses and herbs consumed by cattle in East Darfur.



Note: Numbers in brackets beneath the seasons refer to number of grasses by season.
⋆ Unidentified at the time of writing.

Figure 26 shows the different types of plants eaten by cattle in East Darfur and the frequency with which they were mentioned as one of the top three grasses eaten during the interview period, broken out by season. This shows that the greatest diversity of the diet is during the rainy season.

Trees and shrubs

The study group pastoralists in East Darfur and North Kordofan referred to a total of 26 tree varieties in East Darfur and North Kordofan. The three most common species of trees and shrubs used by cattle in East Darfur were: *Heglig* (*Balanites aegyptiaca*); *Taleh* (*Acacia seyal var. seyal*); and *Mukheit* (*Boscia senegalensis*) (Table 7).

Cattle in East Darfur eat different trees during the late dry season, rainy season, and late rains season. *Heglig* (*Balanites aegyptiaca*), *Shikeat* (*Combretum aculeatum*), and *Taleh* (*Cyprus conglomeratus*) were each mentioned as the three main trees and shrubs consumed during two of the three seasons.

This survey broadly indicates the availability of the most widely used plants. Further, it illustrates the specialist botanical knowledge of this group of pastoralists and their awareness of what their animals were consuming. Because we only asked them to name the top three grasses, we may have missed additional types of grasses. Therefore, this data should not be taken to show the breadth of the pastoralists' knowledge and the botanical diversity they encountered. Nevertheless, this approach was useful in gathering information on livestock nutrition and botanical diversity.

Specialist knowledge of Baggara women

During the year, Baggara women collect and make use of a wide range of grasses, herbs, shrubs, and tree products, including wild fruits, seeds, bark, roots, and foliage, which have multiple local uses and some of which are sold. The availability of these natural products is often seasonal, and some are only available in particular pastoral zones, as described in Table 9. While the use of these wild plants, trees, and shrubs has been noted in earlier studies (Doornbos 1991; Robinson

Table 7. Three most common trees and shrubs used by cattle, camels, and sheep in East Darfur and North Kordofan

East Darfur Cattle	*Heglig* *(Balanites aegyptiaca)*	*Taleh* *(Acacia seyal var. seyal)*	*Mukheit* *(Boscia senegalensis)*
North Kordofan Camel	*Marikh* *(Leptadenia pyrotechnica)*	*Kitr* *(Acacia mellifera)*	*Heglig* *(Balanites aegyptiaca)*
North Kordofan Sheep	*Hemaid* *(Sclerocarya birrea)*	*Mukheit* *(Boscia senegalensis)*	*Subagh* *(Terminalia browni)*

Table 8. Three main trees and shrubs eaten by cattle by season

late dry	*Taleh* *(Acacia seyal var. seyal)*	*Heglig* *(Balanites aegyptiaca)*	*Mukheit/Sedr* *(Boscia senegalensis)*
rains	*Heglig* *(Balanites aegyptiaca)*	*Shikheat* *(Combretum aculeatum)*	*Taleh* *(Acacia seyal var. seyal)*
late rains	*Godeim* *(Grewia tenax)*	*Tokah* *(Cyprus conglomeratus)*	*Shikheat* *(Combretum aculeatum)*

2005; Patel 1994), little attention has been given to their seasonal and ecological specificity and how this fits into and complements the pastoralist seasonal migrations.

Conclusions

The buying and selling of pastoralist livestock from established herds reveals a distinctive marketing strategy among large herd owners. The ultimate goal of the strategy is investment in the herd by improving the quality and increasing the number of livestock. The marketing strategy of the large herd owners is highly seasonal. They use different marketing opportunities throughout the year to improve quality by letting go of older, barren, or unhealthy stock, with a view to investing in younger (thinner) stock. The younger stock can be fattened and improved by, for example, taking them to the Boroya and Butha in South Sudan. There is also recent intensification and expansion of pastoralism to include sheep herds. This new inclusion of sheep herds suggests a clear economic strategy to diversify livelihoods and increase returns. Further examples of diversification of pastoralist livelihoods include the increasing practice of crop cultivation, managed by a part of the household who remain at a more permanent homestead. Farming by pastoralists is partly for subsistence. It can meet daily needs, which reduces the need for pastoralists to sell livestock to supply the family with food. Farming also helps pastoralists to meet their increasing cash expenses.

Pastoralism is often considered to be backward and undeveloped, yet marketing and investment strategies demonstrate a clear economic rationale, with the objective of improving herd quality and size. This section has also shown that specialist knowledge of both men and women is fundamental to the pastoralist way of life. Men have extensive knowledge of their environment and the associated grasses, herbs, shrubs, and trees consumed by livestock, while women know the traditional uses of these plants. Table 9 is a first attempt at a seasonal analysis of the use of various plants and trees by women. While every effort has been made to cross check this information, further work is necessary to validate these findings, review how widely these plants are used, and better understand their social and economic value.

Table 9. Examples of trees, shrubs, and other natural products collected or harvested by Baggara women

Season	Pastoral zone	Name	Notes on preparation and use
All seasons	All	*Al Arat (Albizia amara subsp. sericocephala)*	The leaves from this medium-sized tree are picked and pounded and used to clean wild rice, which has a reddish color. This process helps to polish and whiten the rice.
Deret, seif	All	*Lalob* (fruits from the *Heglig* tree or desert date (*Balanites aegyptiaca*))	Fruit and foliage appear at the height of the dry season. Fruit is produced even in dry years.[7] Fruits can be stored for up to a year if kept dry and free of insects. The fruit pulp is edible and used for drinks. Baggara women process the fruit in the following way. They remove the pulp from the ripe fruit by simmering the fruit and evaporating the water. The mixture is cooled, spread on a mat in the shade to dry, and then pounded to remove the hardened fruit stone, inside of which is the *kornaca* (the kernel). The whole fruit kernel (*kornaca*) is used to prepare *asernei*, a mixture of gum plus extract of *lalob*. *Asernei* is has a sweet and sour flavor and is eaten as a dessert or as a snack. It is particularly useful during migration, when food preparation is difficult, and children or even men cannot wait until the next meal is cooked. It is said to increase thirst and encourage drinking. *Kornaca* and *asernei* are also locally known for their medicinal properties. *Kornaca* can be stored and is sometimes sold. The broken *kornaca* can also be used for tanning hides after boiling in water.
Deret, seif	All	*Erdeb* (fruit) (*Tamerindus indica*)	The tamarind fruits are used as medicine (for malaria) and to prepare drinks, which have a very characteristic sour taste.
Deret, seif	All	*Nabak,* a cherry-like fruit (*Zizyphus spina-christi*)	*Nabak* fruits can be dried and pounded in a calabash and then mixed to a paste with water and boiled or steamed. Once cooked, it can be dried and then cut in pieces for use as a snack food. It is sometimes sold. The dried fruits can be stored.
Kharif	Bahr al Arab, Atmur, Dahara	*Siteb*	This plant commonly grows inside the *rahad* and is identified by its leaves floating on the water's surface. The roots are collected and either prepared or sold fresh in the market.

[7] **http://www.fao.org/docrep/x5327e/x5327e0m.htm**.

continued on next page

continued from previous page

Kharif, deret	Bahr el Arab, Atmur, Dahara	*Ambiegi Koreb* (*Brachiaria xantholeuca*)	*Koreb* is a tufted annual that produces small seeds that are processed in a similar way to wheat in order to remove the outer layers, producing its characteristic white color. *Koreb* is used as a food and can be sold.
Kharif, deret	Bahr al Arab, Atmur, Dahara	*Berdy Roos*/Wild rice (*Echinochloa stagnina*) OR *Koreb* (*Aristida publifolia*))	Following collection, wild rice is air dried, de-husked to collect the seeds, and prepared as rice is.
Kharif, deret	All	*Andarab* (*Cordia rothii*)	Strips of bark from the new branches from this tree are cleaned and used for making floor mats (*shukabah*).
Kharif, rushash	Dahara, Bahr el Arab	*Deleb* (*Borassus aethiopum*)	The branches of this tree are used to make a traditional bed (*daranga*). These are often made in advance of marriage. During *rushash*, the fruits can be eaten.
Rushash	Boroya	*Umbekki*	This is collected during *rushash*, when pastoralists go to the Boroya. It has a very bitter taste. It is first processed, boiled, and cleaned like potatoes, then divided into small pieces and dried, stored in a covered sack for three days, and dried again. It is then ready for use and is generally cooked with meat. It can also be sold.
Rushash, kharif, deret	All	*Gidem*, fruit from *Grewia tenax*	The fruits are eaten by people and animals and are a rich source of iron. Drying extends the storage life of the fruit, which then can be sold. Livestock feed on the young leaves during *seif*. The branches are used for making charcoal, and the bark is used to make ropes.
Seif, deret	All	*Abu Silayleh* (*Aristida mutablis*)	The leaves are used to make mats, which are then often sold in the *souq* (local market).

Part 3. Pastoralism: Role of local governance, relationships, and integration with others

Introduction

Our focus in this section is the relationship between pastoralism and farming and the local governance systems that regulate and manage pastoralist movements and interactions with farmers.

A better understanding of these relationships requires more attention to the social, political, and economic context in which pastoralism is practiced. The southern geographical extreme of the area of these studies is in South Sudan, which is a new nation state in the midst of a protracted and bloody civil conflict. The northern extreme is the sandy *goz* rangelands, where the fresh pastures offer a boost in livestock nutrition for the time of year. In between, pastoralists must pass through farming zones, where livestock routes are encroached by expanding cultivation, causing increasing tensions that sometimes spill over or are linked to tribal rivalries and wider conflict.

Role of local governance in regulating pastoralist mobility and coexistence with other groups

There is an ever-evolving plethora of national- and state-level legislation and accumulated customary principles, norms, and traditions that govern livestock mobility in Sudan.[8] Locally, the tribal administration maintains a strong presence through a hierarchical tribal leadership network, which interfaces with systems of civil and political administration, especially at locality level. This tribal administration, often referred to in Sudan by its earlier official title, the Native Administration, plays a crucial role in governing pastoralist mobility and access to pastoral resources in Sudan and into South Sudan. The *omdas* (mid-level tribal leaders) who were interviewed during our studies felt that tribal administration is becoming less important because "it is not given any importance by the State," and it does not receive any financial support. Despite this, the government does rely on the tribal administration when there are local crises, including conflicts. Others whom we interviewed felt the tribal administration has an important role to play. One interviewee reported that the local representatives are key because "they solve problems in their areas, and they are valued (appreciated) by their people." The structure of the Southern Rizeigat's tribal administration is the following: at the top is the *nazir,* who is the overarching leader. Below him is a deputy *nazir* known as the *wakil*. Below him are 87 *omdas*. Finally, many *sheikhs* (local tribal leaders) report to each *omda*. The *omdas* have an important position of authority within their local area, commanding respect. People in their local areas look to them to address a wide range of community problems.

The Southern Rizeigat tribal administration has a range of responsibilities, including enforcing regulations governing access to water and pasture and supporting local government's taxation of herds, usually made at the start of the pastoralists' journeys north. At the end of the rainy season, when pastoralists are approaching the southern dry season areas (the Bahr), the local tribal authorities regulate their movements to prevent all the pastoralists from leaving at once and racing south to reach the Bahr area first. This regulation of movement allows the tribal authorities to ensure the best use of all available resources by making sure that available fodder on route to the Bahr is utilized. In the past, pastoralist herds would halt in the vicinity of Abu Matariq until the local authorities organized a fire line (Goldammer and de Ronde 2004), and any trespasser moving south before this time would be punished.

In 2015, the delayed and lower-than-average rains precipitated the very early arrival of pastoralists in the south. Pastoralists remarked that

[8] For recent reviews of this institutional and policy context see: Young and Cormack 2013; Behnke 2012; Cormack and Young 2012; Egemi 2012; Gaiballa 2012; Takana, Rahim, and Adam 2012; Krätli et al. 2013; Young et al. 2013.

they either had no recollection of such delayed and poor rains (especially in North Darfur) or otherwise compared it to 1983 (although the poor rains of 1983 were preceded by at least one previous drought year, while 2014 was a relatively good rainy season). Because of the poor rains and early return of many pastoralists, the tribal administration had to relieve the pressure on the area by allowing pastoralists to travel south more than one month earlier than usual.

Tensions as pastoralists move through farming areas

From north to south, the pastoralist cattle herds traverse a vast geographic domain. They walk on the hoof for up to 400 kilometers in two to three months, from the rich savannah of South Sudan to the sandy *goz* plains in the north. Interactions with farmers mainly take place during a relatively small section of their journey, from Totoloto (just south of Abu Matariq) extending northward to Muhajiriya (north of Ed Daein) (Figures 1, 10a, and 10b). Pastoralists frequently complain that farms have extended farther south than ever before, encroaching upon vital rangeland. Various trends have sped up this process, including new cultivation by pastoralists and the increasing size of farms (up to 20 *feddan*, or 8.4 hectares), which is partly due to the shift from hand ploughs to tractors. In the past, farming areas were fewer and more scattered, and started north of Abu Matariq. The tribal administration attempts to solve the problems and the frictions that arise during these annual migrations.

All three official livestock corridors (central, east, and west) that pass through these intensively farmed zones have become increasingly narrow in the cultivated zone and sometimes are blocked completely by ploughed or sown fields. Our study group of pastoralists describe the high tensions as they pass through this area. They reported that they must be alert at all times, maintaining a watch on their herds day and night to prevent them from straying and causing damage to farmers' crops. They also reported problems of thieves and highwaymen. As they describe it, they cannot relax until their herds have reached the *goz* areas.

The increasing fencing-off of rangeland by *zariba al hawa* (air enclosures) is a related issue. This practice of fencing rangeland areas with thorny branches preserves pasture for the farmers' own personal use. Individual farms usually include cultivated fields, air enclosures to fence off pasture, and a permanent settlement or homestead for the owner, which, combined together, take up a large area. The fenced-off pastureland is usually preserved for the owners' sheep and goats. Sometimes he sells grazing rights on this land to others. Alternatively, some farmers plant their fields in a circle, thus preserving an inner area of rangeland that by design restricts access by other herds. These trends mean that once pastoralist herds are inside the corridor, there are few places for cattle to graze freely, and they must travel quickly to reach open *goz* rangelands to the north.

The number and size of farms and herds are increasing over time, resulting in frictions on all sides. In East Darfur, the farmer-herder disputes are not necessarily divided along tribal lines, because the Southern Rizeigat are increasingly farming and herding livestock, so pastoralist herders may have disputes with pastoralist farmers.

Role of the tribal administration in addressing farmer-herder conflicts

The tribal administration actively tries to mitigate any tensions with farmers by inspecting the farms and issuing advance warnings to farmers to expect pastoralist herds. Despite these precautions and efforts, problems remain and pastoralists speak of this time as one of "difficulties and suffering." The problems they face are significantly worse when travelling from north to south because of the risk that their livestock will damage crops. When pastoralists are moving north, most farmers are in the stages of land preparation and sowing, so the risk is much less.

The law regarding cultivation within the corridor is clear, and neither farming nor air enclosures are allowed within the corridor area. During the annual passage of pastoralists through the livestock corridors, incidents do

occur, and there are many examples of livestock damage to crops[9] and livestock or herders being taken into custody.

According to the senior tribal leadership of the region (*omda*), there are three levels of problems linked with farmer-herder disputes:

1. Small individual problems solved by the people within the *farig*. This is the majority of cases.

2. Cases where there is more harm done; for example, someone is beaten, or there is an intentional or unintentional killing of one or two persons. These cases are taken to the tribal administration and are then subject to the traditional authorities and laws.

3. Problems between clans (*hashmel bait*) or tribes. These conflicts are raised to a higher level for resolution within the tribal administration. Conflicts between two tribes are resolved through a tribal conference, which is usually mediated or hosted by a third tribal group.

There is a vast difference between the third case—tribal conflicts—and the many smaller, individual cases that are very often solved locally. One of our study group pastoralists described the steps they take in addressing a local-level dispute:

> "When we meet a difficulty inside the corridor, such as friction with farmers, we sit together to solve it. Before we go to the Native Administration, we can approach the local Popular Committee and the police. So we take the people to this committee, and we sit with the police to resolve the problem. If it does not work, it then goes to the Native Administration, and it is for them to go to the higher authorities as necessary. We have mediators (*ajawid*), popular committees or panels (*legna shabi*), and local tribal authorities to help us resolve these problems."

Regionally there may be differences in the way trespassing and crop damage are addressed. For example, in the north of the region, a group of neutral mediators known as ajawid preside. These mediators are neither relatives nor otherwise associated with the victim or perpetrator's families. In the south, the custom is to use a joint court where both sides meet as equals (*legna shabi*).

Under the traditional laws, there are agreed rules and payments to the victim and the victim's clan, including rules about how the payment or blood money (*diya*) should be divided between the victim and the clan. For example, blood money is half as much for unintentional killing as for intentional killing. In most cases, the blood money is paid in live cattle. Payments also vary according to the relations between the groups involved, for example:

- When the dispute is between two *omidiyat* (the area administered by an *omda*) from the same tribe (a blood relationship), the fine is 40 cows, with 50 percent to the victim and the rest divided between the *omidiyat*.

- When the dispute is between three *omidiyat* with no blood relations, the blood money is 60 cows, plus an offering (for example, one bull to be slaughtered).

- For a dispute between neighboring tribes, the blood money is usually 71 head of cattle.

Problems of blocked corridors are not only a result of farmer-herder conflicts. As was evident in our 2013 study, inter-tribal conflict can prevent the passage of pastoralist herds along corridors. Our first livestock monitoring report (Young et al. 2013) describes how an inter-tribal conflict unfolded and had a marked effect on the movement of the tracked pastoralist herds. With the outbreak of violent conflict and many deaths on both sides, the pastoralists moved to the west

[9] One example given was the case of 80 head of cattle trespassing on a farm in the Birgid area. The farmer took the herder to the police. The herder was put in prison and told to pay a ransom of 13,500 Sudanese Pounds (SDG) (about USD 2250), before he would be released. Another case involved livestock trespassing on farmland and the owner taking the animals and confining them within a small enclosure. The owner of the animals did not find out where his animals were until the following day, when he was asked to pay 5,000 SDG for their return (just under USD 1,000). He refused and took the case to a higher committee to appeal. He ended up paying 2,500 SDG.

to another corridor to keep away from the heart of the problem. This situation reduced their mobility, added to the length of their journey, and required careful negotiations on their part with farmers along the way. They described how this conflict produced major problems. The eastern corridor in East Darfur is now blocked, forcing larger numbers to use the central and western corridor. There is a clear impact on the provision of services in the area, and there are increasing dangers as they travel northward on these routes.

South Sudan: Relations between the Southern Rizeigat and the Dinka Malual

When the Southern Rizeigat pastoralists cross the border into South Sudan, a different set of rules and regulations come into play. Since the secession of South Sudan, the Southern Rizeigat tribe has met with the Dinka Malual at an annual "pre-migration conference." The conference was held in 2013, 2014, and 2015. It usually takes place at Gok Machar, Nyamliell, or Aweil, Northern Bahr el Ghazel. These conferences are "necessitated by their mutual needs: water, pasture and trade" and the lessons arising from "their devastating experiences of series of civil wars whose prices they paid heavily" (Anon 2014c, 1). These conferences have had a major positive impact on inter-tribal relations and resulted in high-level agreements between the two tribes. At the conference, the tribes discuss all the issues of the past dry season when Southern Rizeigat pastoralist herds were in South Sudan. They review in detail any violations on either side to ascertain whether any crimes have been committed and if they have, agree on and arrange the payment of fines.

The negotiated agreements reflect common interests around trade, access to rangeland, pasture, and water, and also rules relating to environmental protection. The Dinka Malual and Southern Rizeigat have agreed to a series of resolutions governing their relationship, including certain conditions relating to pastoralists and pastoralism. They are summarized in Box 2.

Box 2.

Extracts from the resolutions between the Dinka Malual and Rizeigat 2014 pre-migration conference, held in Aweil North County, South Sudan, January 23–25, 2014 (Anon 2014c).

- Period of migration and movement of Rizeigat from eastern Darfur to South Sudan shall start on [*between*] the first week of January to the first week of June upon the delay of rainfall.
- All cattle entering the Republic of South Sudan ought to be vaccinated at the entry points along the migration routes.
- Compensation for intentional killings shall be 41,000 South Sudanese Pounds (SSP)[10] or its equivalent. Compensation for unintentional killings shall be 31 heads of cattle or 31,000 SSP or its equivalent. An additional fine of 10,000 SSP will be paid to the relevant local government authorities.
- Neither side shall come with firearms.
- Rizeigat pastoralists are prohibited from herding livestock on residential areas and farms. Any claims of destruction of property by cattle/goats shall be assessed by the joint peace committees, courts, and local government authorities for compensation.

continued on next page

[10] The value of the South Sudanese Pound against the US Dollar has fallen since 2014, from 3.1 on June 1, 2014, to 18.5 on December 31, 2015 and 40.2 on June 30, 2016, based on the United Nations operational exchange rates: **https://treasury.un.org/operationalrates/OperationalRates.php#S** (accessed July 19, 2016). Local rates are likely to differ from these.

continued from previous page

- Rizeigat and Dinka Malual shall ensure that their counterparts who are in their territories for any purposes will be ensured complete protection of life and property.
- Rape and adultery cases shall be penalized by payment of 15 head of cattle or 15,000 SSP [*for rape cases*] and 7 heads of cattle or 7,000 SSP [*for adultery cases*].
- Abduction of women and children is prohibited.
- Burning of grass and bushes, naming and renaming of places, poaching, and marking and cutting of trees are categorically prohibited.
- Any security incidences associated with the Sudan People's Liberation Army (SPLA) and Sudan Armed Forces (SAF) involving civilians from the two countries of South Sudan and Sudan shall be reported.
- The two parties agree to form a joint border court and peace committee to resolve outstanding issues.
- Facilitation of movement of goods and services along the border.
- Pastoralists should adhere to official acceptable routes of migration during entry into and exit from Dinka Malual territory.

These agreements also cover the issue of "development fees," which are paid by the pastoralists to the local government in South Sudan. They pay 700 SDG per herd for use of pasture and water in the area (irrespective of the specific size of the herd). This fee may also entitle the herd to be part of any vaccination campaigns that take place while they are in the area. The fees have increased since South Sudan's secession, but there has always been a payment of fees.

Before secession, the government of Sudan did not allow the Southern Rizeigat tribal leadership to formally enter the area of South Sudan to negotiate the conditions for pastoralists to enter. So in the past, rights for their livestock to graze and use water in the area were negotiated at a "lower level" but still involved a fee payment, which was less than the current payments.

The local Rizeigat tribal administration plays a crucial role in negotiating and then upholding these agreements. They convene local conferences on the return of pastoralists from South Sudan to review any problems that were experienced (see Figure 27 for a photo of a local tribal meeting in the Bahr area). If they cannot solve these problems locally, they are brought to the higher-level Dinka Malual and Rizeigat annual conference.

As in East Darfur, in South Sudan any problems are first addressed at a local level between the people concerned. The study group pastoralists explained that they usually pay immediately if their cattle have entered a farm in South Sudan in order to solve the problem locally with the farmer. If there are violations that are not solved immediately, there is a local joint border court that can be convened. The joint border court includes two panels: five people from the Southern Rizeigat tribe and five people from the Dinka Malual. Again, the penalties are often livestock fines. This court also regulates social relations. For example, they impose a fine of 7.5 cattle for cases of consenting adultery and 15 cattle in the case of rape.

The blood money between the Southern Rizeigat and the Dinka Malual is 30 head of cattle for wrongful killing and 41 cattle for intentional killing. The fines are usually first calculated according to the local currency, but usually people then prefer to receive their payment in cattle.

Figure 27. Tribal meeting in East Darfur (February 2015).

Most significantly, these tribal agreements avoid or mitigate particular problems that each group faces. For the Southern Rizeigat, the agreement allows them to access vital dry season pastures, the only area where there is sufficient pasture and water for large herds at the peak of the dry season. For the Dinka Malual, the agreement supports a vital trade link with Sudan and preserves a source of essential goods. It also ensures a friendly tribe on their northern border in a region that could potentially host opposition or, for example, when relations between their two governments might look very different. This latter point is important in the context of wider civil war in South Sudan. The Southern Rizeigat Native Administration has agreed that it will not allow anyone to attack Dinka Malual in Southern Rizeigat areas. In December 2015, the Nuer had a military camp inside East Darfur, and they were ordered by the Rizeigat Native Administration to evacuate. If they had not evacuated, the Rizeigat would have dealt with them to honor their agreement with their Dinka Malual neighbors.

As explained by a tribal leader, the biggest factor in securing this agreement is that the Southern Rizeigat "need access to the grazing areas in the south, and cannot do without it." They are "forced to go there for watering. And we know their (the Dinka) nature, they are a very peaceful people, who do not like problems, they know our capabilities, and so they avoid to get into a clash with others, as do the Rizeigat pastoralists."

Thus, the relationship is one of necessity. When asked whether there is anything that could possibly disturb this relationship, the *omda* described how relations between the two countries' governments could affect their local situation. If relationships deteriorate, for example, the agreements are likely to stop if the State authorities decree they must stop. At present, although the government of Sudan is not involved in driving or supporting this agreement, they are perceived as allowing these relationships and agreements to proceed. If there were to be a problem between the two governments, then potentially livestock could be prevented by fencing from crossing into the south, although, according to the *omda* "in the end it would be a problem at the level between the two States (countries), as pastoralists can usually find a solution locally."

Inter-tribal conflicts: What link, if any, to pastoralist mobility?

Inter-tribal conflicts have wracked the Darfur region for decades, and in East Darfur violent tribal conflict has spiked since 2013. In this conflict between the Southern Rizeigat and the Ma'aliya alone, hundreds, if not thousands (Anon 2014b), have been injured or killed in the past three to four years, and tens of thousands have been displaced. Each year local, regional, and national actors have attempted to restart peace and reconciliation processes but have been unable to secure a lasting peace.

The Southern Rizeigat and Ma'aliya conflict is the oldest of the inter-Arab conflicts that continue in Darfur (ICG 2015). This conflict over administrative and judicial rights dates back to the 1960s (Takana 2008; Flint 2010). Two key changes have potentially contributed to this conflict's persistence and recent rekindling: first, the Ma'aliya gained access to their own administrative unit in 2004 after being under Rizeigat control since independence (O'Fahey and Tubiana 2007), and second, petroleum has been discovered in Ma'aliya-controlled areas (Anon 2014a).

The Southern Rizeigat received their own *dar* (tribal homeland) and hakura (traditional land tenure system) under the colonial regime. Their authority continued upon independence, and they are by far the majority tribe in East Darfur, with strong tribal links with northern Rizeigat (*abbala*, or camel herders) in the wider region. The Ma'aliya, on the other hand, have only recently gained access to their own tribal administration and land and are a much smaller tribe, with far less political representation than the Southern Rizeigat (Young et al. 2013).

The fighting has had impacts on local civilians, with assassinations, thefts of livestock, and reprisal killings. Some larger confrontations, however, have led to dozens of deaths and renewed calls for peace and reconciliation from regional and national governments and the United Nations–African Union Mission in Darfur

(UNAMID). Multiple politicians have called on the Government of Sudan to send soldiers and police to the area to keep the peace.

Commentators universally see the conflict as driven by land, resource competition, and tribal boundaries (Takana 2008). Up to this point, as the International Crisis Group laments, the multiple peace and reconciliation processes have been "unable to address the conflict's root cause: land" (ICG 2015, 10).

Humanitarians, journalists, and academic researchers have commented on the environmental stresses associated with drought and have suggested that these stresses contribute to conflict. For example, the head of the United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA) office in Sudan said in 2013 that "indeed, much of what is commonly referred to as 'inter-tribal fighting' or fighting over 'economic resources' actually relates primarily to disputes over land and access to water and grazing for animals" (IRIN 2013).

In contrast to many of the other tribal conflicts in Darfur, the conflict between the Ma'aliya and Southern Rizeigat has not been widely studied and reported. Likewise, there is a dearth of published reports on conflict over natural resources in Darfur covering the scale, characteristics, and impact. This lack has led to a certain degree of unhelpful muddling between tribal conflicts associated with seeking land rights and chieftaincies linked with political power on the one hand, and local-level disputes between individuals over access to water and pasture on the other. It also further perpetuates misperceptions and misunderstandings of tribal conflict and ignores the realities of how pastoralists manage the variable natural distribution of water and pasture. These widely-held misperceptions about pastoralism and conflict remain one of the major obstacles to longer-term peace and stability in the region. Crucially, this review did not uncover any studies or evidence demonstrating the link between pastoralist migration, environmental stress, and this particular tribal conflict.

Conclusions

Local-level disputes between those who farm and those who raise livestock are somewhat removed from the inter-tribal conflict over land and wider civil and transnational conflicts, yet these disputes have a profound effect on the resilience and sustainability of the two main livelihood production systems in the region. A comprehensive solution to these local natural

resource conflicts requires a more evidence-based, locally driven understanding of how these livelihood systems interact and the local institutions that manage access to natural resources. There is evidence of effective local-level resource management by tribal authorities. This positive experience needs to be built upon and shared with key local and national stakeholders. Extending this understanding is crucial for the development of the region and for peace and reconciliation from the local level upwards.

Conclusions and recommendations

The study findings and analysis produced five broad conclusions, each of which led to specific recommendations that are presented below.

Mobility as a strategy to turn temporary deficiencies to advantage

Pastoral mobility is a strategy that attempts to avoid the hazards and exploit the opportunities offered by variable and often unpredictable rangeland environments. In migratory systems, livestock move sequentially across a series of environments, which reach peak carrying capacity (optimum conditions for livestock) at different times, thereby avoiding resource scarcities and exploiting optimal periods in each area used.

It is commonly said that pastoral nomads and their herds chase the rains, but we found no indication in our data that pastoralists pursue individual rainfall events. Common sense also suggests that migratory livestock should move to the places where they can find the most food. However, in the Sudan-Sahel region in general and in East Darfur in particular, pastures that produce large quantities of plant material routinely produce poor-quality livestock feed. This reality presents livestock owners in East Darfur with a dilemma. They can go to places that contain the most feed or to places that produce the best feed, but they frequently cannot meet all their requirements in one place. Pastoralists reconcile this dilemma by moving to southern areas with large amounts of low-quality feed in the dry season when feed is scarce and their primary concern is to find enough for the animals to eat. They then move to northern pastures with high-quality, more nutritious feed in the rainy season when plant material is abundant and they can afford to be selective. The exact timing of these moves is calibrated to the growth cycle of the pastures. Pastoralists in East Darfur extend the availability of nutritious, green forage by exploiting asynchronous cycles of plant growth and die-back. During the rains, this variability can be found on a zonal, spatial scale, and herds move from zone to zone to optimize their access to fresh plant material. In the early dry season, pastoralists exploit microvariations in topography and set fires that "reset" the developmental clock and stimulate out-of-season plant growth in low-lying areas.

The underlying scientific rationale for mobility and the nutritional benefits of this strategy for livestock are not generally well understood, in part because they run counter to established western models of ranching and also in part because of a lack of specific evidence that shows the relationships between rainfall, pasture, and mobility that pertains to the entirety of an actual pastoralist system.

The study reported on here has begun a process of documenting the specialist expertise of migratory herd managers in eastern Darfur and the ecological advantages of their mobile production strategy. However, this study is only a start. It involved a small number of herders in part of one state in Darfur. Because of security concerns, in recent decades there has been a dearth of field research on all aspects of rural and urban life in western Sudan, especially livestock production. Policy cannot be reliably formulated in an evidence vacuum. The increasingly important contribution of livestock to Gross Domestic Product (GDP) and exports underlines the practical implications of pastoralism for the national economy. At the same time, a shift in the negative views of pastoralism that are widespread in society would significantly enhance the image of the sector, among local and national stakeholders and for the next generation of pastoralists, who may otherwise be drawn to other livelihoods.

Recommendation: Understanding pastoralist mobility

1. A strategic program to build awareness—both among officials and the public at large—of the role and importance of pastoralism in Sudan should be coupled with demand-driven applied research. There has been significant progress in promoting awareness of the

scientific basis for pastoralist mobility to stakeholders across government ministries (livestock, water, environment, agriculture) and throughout civil society; this has been achieved through a program of capacity development and policy review. Further efforts are needed to develop and implement this program of knowledge transfer and skills development (based on adult learning techniques) through universities, technical institutions, and professional networks, building on the earlier successful work of the UNEP Sudan Integrated Environment Programme. Specifically, key pastoralist stakeholders within government, civil society, and the traditional authorities should be targeted to raise their awareness and increase their capacity to articulate the rationale for pastoralism.

Water and pasture: Two vital and related issues

During the dry season, the Bahr area in East Darfur is host to vast numbers of livestock and pastoralists. Seasonal markets meet many of the pastoralists' needs, but there remain huge pressures on local services at this time of year.

The number-one issue and priority need for pastoralists in East Darfur during the dry season is water availability and quality. They currently depend on the system of shallow hand-dug wells (*edad*), seasonal pools, and marshy areas. The quality of the marshy areas noticeably deteriorates with the advancing dry season. Despite the increasing success of the livestock sector, the number of seasonal water reserves (*hafir*) and operating water yards (*dwanki*) has dropped as water yards fall into disrepair. Access to pasture by livestock is determined by access to water, because water limits the distance livestock can move for grazing in between watering, and so the two facets should be considered together. Development planning of water resources prioritizes the more permanently populated (farming) areas of East Darfur, while ignoring the acute dry season needs of pastoralists from the wider region when they are concentrated in the Bahr. Planning of water resources for pastoralists requires inter-ministerial coordination, and the Federal- and State-level Ministry of Livestock, Fisheries and Range are in a strong position to work with other Ministries in developing this further.

Recommendation: Planning and coordination of basic service delivery

2. Dry season planning of service delivery must take account of seasonal demand associated with livestock migrations into and out of different areas. Water resource planning in particular must take account of and address the needs associated with seasonal migration of pastoralists, for watering their livestock, while still enabling them to access sufficient pasture and fodder. Thus, efforts to develop water resources in the region must be closely planned and coordinated between the Ministry of Livestock, Fisheries and Range, (Range and Pasture Department), the Public Water Corporation, the Ministry of Environment, and pastoralist representatives (tribal administration and committees that manage the shallow well system) to share their expertise. Issues to consider include: different livestock watering requirements and proximity to pasture; distances that different species travel between watering; delivery systems that minimize overcrowding and overgrazing; complementarity between different water systems; management and fees; and impact on both the local environment and other water users, and ways to combat this impact.

Pastoralist livestock marketing strategies—aim of investing in the herd

The report describes a pastoralist investment strategy among larger herd owners. These pastoralists aim to invest in their herds by buying thin but healthy animals from small producers before they take their herds to the Bahr. In the Bahr, these animals are fattened with the arrival of the rains (which start earlier further south). They are then sold in the main markets on their journey north, where they will fetch higher prices than in the south.

Only producers with sufficiently large herds and expertise can play the market in this way. This strategy takes advantage of the predicament of the small pastoralist producers, but does not harm them. It may even help by providing a productive outlet for weak but basically sound sedentary stock, thereby sustaining a market and price for these animals to the advantage of their owners.

Another trend is that pastoralists are increasingly interested in expanding their herds to include sheep (as well as increasing numbers of cattle). We do not yet understand the implications of including these animals in herds for resource use (water, pasture, and fodder) and the regions' economy. This area needs to be studied.

Recommendation: Livestock marketing

3. Conduct studies of the environmental and economic implications (if any) of expansion of pastoralist production to include sheep herds at these latitudes, and implications for cattle herds.

Farming and herding: Integrated by form, function, and necessity

The relationship between farming and herding is somewhat complex. Integration of these two production systems must be viewed from different perspectives and at different scales, from the household to the local community and then across a much wider geographic domain encompassing the entirety of the pastoralist and agricultural systems. At the household level, the two activities are frequently integrated as part of household livelihood. We have seen pastoralists frequently farm and farmers often raise livestock. Thus, our concern is not the self-identification with a pastoralist or farming group, but rather the practice of farming and pastoralist livestock production.

Both production systems depend on natural resources, which are governed by a plurality of land tenure regimes, including sharing of common property resources, the traditional *hakura* system (that allocates farming rights), sharecropping, and individual ownership. Importantly, the traditional land tenure arrangements support shared use of land by multiple users at different times of the year.

Farming and raising livestock underpin household and regional food security and form the basis of the local economy. Our data show that when herds move through the heavily farmed zone, they are in rapid transit and do not graze extensively, as their aim is to reach the uncultivated rangeland to the north. Relatively little potentially farmable land is needed for these narrow transit corridors, and the payoff from maintaining the livestock corridors (which open up northern rainy season grazing areas) is almost certainly better than the payoff from a marginal expansion of the farmed area, which leads to the twin problems of damage to crops and blocked livestock corridors.

In some instances, competition over natural resources as pastoralists move through farming areas can lead to local-level conflict, which escalates to violence. This starts at the level of disputes between individuals or small groups. Tribal governance systems have long existed to deal with these disputes and are widely acknowledged at the local level to be the best way of dealing with them (Sharawi and Gaiballa 2010).

Livelihoods analysis often categorizes populations into fixed livelihood groups according to their livelihood strategies. This approach often fails to take into account ways in which different production systems are integrated around shared interests. Outsider perceptions of fixed social groups, each with their own individual interests, highlight differences and potential sources of competition and conflict, thus leaving less room for analysis of integration. A fixed group perspective also risks ignoring the more flexible livelihood strategies that are commonly practiced by "groups" in an attempt to manage the twin considerations of extreme rainfall variability and shared use of natural resources. In other words, in a context such as Darfur, all land users are facing the same extreme climate variability, which must be factored into their livelihood strategies.

The past decade has seen national and international NGOs investing in projects to demarcate livestock corridors, in all states of Darfur and also in Kordofan, yet this breadth of experience has yet to be evaluated. Some project experience is very promising and can help to inform a clear policy and practice for development of livestock corridors in the current context.

Recommendations: Farming and herding

4. Evaluate the recent programmatic experience demarcating livestock corridors, including implications for livestock health, farming, social relations, marketing, and environmental management.

5. Conduct a land use study to analyze changes in the area devoted to crop farming, the reasons for these changes, and the implications of these changes for access to grazing land and the maintenance of livestock corridors.

6. Promote a positive shift in attitudes towards pastoralism and pastoralist mobility and a better understanding of the challenges experienced in farming and pastoralism (building on Recommendation 1).

Governance of pastoralist mobility: What works? What remains to be done?

The functioning local governance mechanisms—through the tribal administrations—are a huge resource. These mechanisms perform a wide range of essential duties in relation to pastoralist mobility that promote the rational use of all available resources. This includes regulating the movement of pastoralists on their way to the Bahr and the management of the dry season wells.

This particular study has shown the crucial importance of the "escape hatch" of allowing larger herds to move into South Sudan, thereby reducing pressures on the Bahr area in the dry season. This movement south is especially important in dry years such as 2015, which has been described as the driest since 1983. The "escape hatch" is based on necessity; both groups have particular needs, accommodated in the Southern Rizeigat–Dinka Malual agreements, needs that are well understood and prioritized by both sides. Through their annual conferences, the Southern Rizeigat and Dinka Malual appreciate their mutual interests and the necessity of negotiating the pre-migration agreement.

In contrast to the improved relations with neighbors in the south, the spike in inter-tribal conflict in 2013 has now persisted for nearly three years, leaving a trail of failed conflict resolution mechanisms. The situation of blocked pastoralist migration as a result of inter-tribal conflict is far less well understood than other impacts of conflict, such as forced displacement. Blocked migration has a damaging impact on individual pastoralists and requires them to take immediate action to relocate their herds, which in the farming zone can be a challenge and increase tensions locally.

Herder-farmer conflicts are usually disputes between individual land users whose livelihoods are equally threatened. In practice, the disputes are best dealt with locally, involving local tribal leadership as needed. These disputes are sometimes tangentially linked to deeper, long-running conflicts as a result of the tribal affiliations of herders and farmers and their long and shared history. Hence, the two types of conflict are connected, but these local disputes are only superficially relevant to higher-level conflicts, while the higher-level conflicts directly impact livelihoods at a local level. It is therefore often incorrect to infer (as many external commentators do) that these local-level farmer-herder disputes are the direct or indirect cause of wider, higher-level conflicts.

Recommendations: Governance of pastoralist mobility

7. The Southern Rizeigat and Dinka Malual pre-migration conferences and meetings have been hugely successful in providing a forum for negotiating access and addressing problems for Rizeigat pastoralists travelling to South Sudan. Such initiatives have been supported by external donors. Donors should continue to support these conferences, at least until the wider situation stabilizes.

8. Greater recognition by the national and regional authorities is required of the crucially important role of the tribal administration in supporting pastoralist mobility. Members of the tribal administration are involved in considering how the specific needs of conflict-affected pastoralist herds might be supported. The tribal administration negotiates with

local tribal leaders to identify nearby resting areas and places where water and fodder supplies can be provided on an emergency basis.

9. The coordinating body of the international Livestock Emergency Guidelines and Standards (LEGS 2015) should be encouraged to review how conflict affects pastoralist mobility. The coordinating body should consider how this could be addressed by local humanitarian actors in the next edition of the Standards.

References

Abdelrahman, M. M., R. L. Kincaid, and E. A. Elzubeir. 1998. "Mineral deficiencies in grazing dairy cattle in Kordofan and Darfur regions in Western Sudan." *Tropical Animal Health and Production* 30:123–135.

Abdel Rahman, I. M K. 2007. "Sudanese cattle resources and their productivity. A review." *Agricultural Review* 28 (4):305-308.

Adger, W. Neil. 2000. "Social and ecological resilience: Are they related?" *Progress in Human Geography* 24 (3): 347–364.

Anon, 2013. Cell Guide Robin User Manual Version 8, June 2013.

Anon. 2014a. "Fresh tribal clashes erupt in East Darfur." *Sudan Tribune*, August 20, 2014. Accessed 04/10/2016/19:36:35. **http://www.sudantribune.com/spip.php?article52119**.

Anon. 2014b. "Over 300 killed in clashes between Rezeigat and Ma'alia in East Darfur." *Sudan Tribune*, August 31, 2014. Accessed 04/03/2016/16:49:10. **http://www.sudantribune.com/spip.php?article52238**.

Anon. 2014c. Resolutions between Dinka Malual and Rezeigat. 2014 pre-migration conference, held at Peace Center in Aweil North County, Gok Machar, Northern Bahr el Ghazal State, Aweil, Republic of South Sudan, January 23–25, 2014.

Behnke, Roy. 2012. "The economics of pastoralism." Pastoralism policy working paper series. Khartoum: Feinstein International Center, Tufts University Friedman School of Nutrition Science and Policy and United Nations Environment Programme.

Behnke, Roy, and Hala Mohamed Osman. 2010. "The contribution of livestock to the Sudanese economy." IGAD (Intergovernmental Authority on Development) LPI (Livestock Policy Initiative) working paper No. 01-12. IGAD Livestock Policy Initiative, Odessa Centre.

Behnke, Roy, M. E. Fernandez-Gimenez, M. D. Turner, and F. Stammler. 2011. "Pastoral migration: Mobile systems of livestock husbandry." In *Animal migration: A synthesis*, edited by E. J. Milner-Gulland, J. M. Fryxell, and A. R. E. Sinclair, 144–171. Oxford: Oxford University Press.

Blaxter, K. L., and F. W. Wainman. 1961. "The utilization of food by sheep and cattle." *The Journal of Agricultural Science* 57 (3): 419–425.

Breman, H., and C. T. de Wit. 1983. "Rangeland productivity and exploitation in the Sahel." *Science* 221 (4618): 1341–1347. doi: 10.1126/science.221.4618.1341.

Calenge, C. 2015. "Adehabitat package for R: Analysis of habitat selection by animals." Version 1.8.18.

Christian, C. 1958. "The concept of land units and land systems." Ninth Pacific Science Congress.

Cormack, Z. and H. Young. 2012. Pastoralism in the new borderlands: Cross-border migrations, conflict and peace-building. Working paper. Pastoralism policy working paper series. Khartoum: Feinstein International Center, Tufts University Friedman School of Nutrition Science and Policy and United Nations Environment Programme.

Dawelbait, E. M., G. B. Gadalla, and I. Bushara. 2011. "Productivity of desert sheep under grazing condition in North Kordofan, Sudan." *Online Journal of Animal and Feed Research* 2 (4): 344–347.

Dee, D. P., S. M. Uppala, A. J. Simmons, P. Berrisford, P. Poli, S. Kobayashi, U. Andraec et al. 2011. "The ERA-Interim reanalysis: Configuration and perfomance of the data assimilation system." *Quarterly Journal of the Royal Meteorological Society* 137:553–597.

Doornbos, Paul. 1991. "Botanical survey of the Chad-Sudan border area: Gramineae." Cinquieme Colloque Mega-Tchad. L'homme et le milieu vegetal. September 18–20, 1991, Paris.

Egemi, O. 2012. "Pastoralist peoples, their institutions and related policies." Pastoralism policy working paper series. Khartoum: Feinstein International Center, Tufts University Friedman School of Nutrition Science and Policy and United Nations Environment Programme.

Fahey, Dan. 2007. "Key issues for livestock and pastoralism in Sudan." IGAD LPI policy brief. Addis Ababa, Ethiopia: IGAD Livestock Policy Initiative.

Fahey, Dan, and David K. Leonard. 2007. "The political economy of livestock and pastoralism in Sudan." IGAD LPI working paper No. 06-08.

FEWS NET. 2015. "Sudan food security outlook update." December 2015. Khartoum.

FEWS NET. 2016. "Sudan food security outlook update." Khartoum.

Fitzpatrick, Merry, and Helen Young. 2015. "The road to recovery: A scoping study for the Taadoud Transition to Development Project." Feinstein International Center, Tufts University Friedman School of Nutrition Science and Policy.

Flint, Julie. 2010. "The other war: Inter-Arab conflict in Darfur." Small Arms Survey, Graduate Institute of International and Development Studies, Geneva.

Fryxell, J. M., J. F. Wilmshurst, and A. R. E. Sinclair. 2004. "Predictive models of movement by Serengeti grazers." *Ecology* 85 (9): 2429–2435.

Gaiballa, A. 2012. "Natural resources, governance and pastoralism in Sudan." Pastoralism policy working paper series. Khartoum: Feinstein International Center, Tufts University Friedman School of Nutrition Science and Policy and United Nations Environment Programme.

Georgiadis, N. J., and S. J. McNaughton. 1990. "Elemental and fibre contents of savanna grasses: Variation with grazing, soil type, season and species." *Journal of Applied Ecology* 27 (2): 623–634.

Goldammer, Johann G., and Cornelis de Ronde. 2004. *Wildland fire management handbook for Sub-Sahara Africa*. Global Fire Monitoring Center.

Harrison, M. N., and J. K. Jackson. 1958. "Ecological classification of vegetation of the Sudan." In *Forests Bulletin No. 2 (New Series)*. Khartoum: Agriculture Publications Committee, Forests Department, Ministry of Agriculture.

Holdo, Ricardo M., Robert D. Holt, and John M. Fryxell. 2009. "Opposing rainfall and plant nutritional gradients best explain the wildebeest migration in the Serengeti." *The American Naturalist* 173 (4).

HTS (Hunting Technical Services). 1974a. "Land use planning survey in Southern Darfur, annex 1: Soil and vegetation resources."

HTS. 1974b. "Land use planning survey in Southern Darfur, annex 3: Animal resources and range ecology."

HTS. 1975a. "Savanna development project, phase II, land use planning survey in Southern Darfur, annex 1: Soils and vegetation."

HTS. 1985. "Planning regions of the western savannah phase II project area." Borehamwood, Herts, UK: Hunting Technical Services.

ICG. 2015. "The chaos in Darfur." *Crisis Group Africa Briefing* 110.

International Commission of Inquiry. 2005. Report of the International Commission of Inquiry on Darfur to the United Nations Secretary-General. Pursuant to Security Council Resolution 1564 of 18 September 2004. Geneva.

IRIN. 2013. "The humanitarian situation in Darfur." **http://www.irinnews.org/report/98580/briefing-humanitarian-situation-darfur**.

Ismail, A. B. O., Y. R. Sulaiman, F. A. Ahmed, and H. A. M. Ali. 2015. "Effect of stages of maturity on nutritive value of some range herbage species in low-rainfall woodland savanna Southern Darfur, Sudan." *Open Journal of Animal Sciences* 5 (1): 1–8.

Krätli , Saverio, Omer Hassan el Dirani, Helen Young, with Samira Mohammed Ahmed, Osman Mohammed Babiker, Musa Adam Ismail, Abdelazeem Hassan, and Azharia El Bushra. 2013. "Standing wealth: Pastoralist livestock production and local livelihoods in Sudan." United Nations Environment Programme.

LEGS. 2015. *Livestock emergency guidelines and standards (LEGS). Second edition*. Rugby: Practical Action Publishing.

Malechek, J. C. 1984. "Impacts of grazing intensity and specialized grazing systems on livestock response." In *Developing strategies for rangeland management*, 1129–58. Boulder, Colorado and London: National Academy of Sciences and Westview Press.

Mendzylewski, D. 2013. Robin PC Software Installation Guide Rev 1.0.

O'Fahey, R. S., and Jérôme Tubiana. 2007. "Darfur: Historical and contemporary aspects." Action Contre La Faim and UNMIS (United Nations Missions in Sudan).

Osman, Abdal Monium Khidir. 2013. "Agricultural change, land and violence: An examination of the region of Darfur, Sudan." PhD thesis for Doctor of Philosophy in Food Policy and Applied Nutrition, Gerald J. and Dorothy R. Friedman School of Nutrition Science and Policy, Tufts University.

Owen-Smith, N., and P. Novellie. 1982. "What should a clever ungulate eat?" *American Naturalist:* 151–178.

Patel, M. 1994. "An examination of the 1990–91 famine in Sudan." *Disasters* 18 (4): 313–331.

Pettorelli, N., S. Ryan, T. Mueller, N. Bunnefeld, B. Jedrzejewska, M. Lima, and K. Kausrud. 2011. "The Normalized Difference Vegetation Index (NDVI): Unforeseen successes in animal ecology." *Climate Research* 46:15–27.

Pica-Ciamarra, Ugo, Simplice Nouala, and Sunae Kim. 2011. "Livestock and livelihoods in the IGAD region: A policy and institutional analysis." IGAD LPI working paper No. 01-11.

R Development Core Team. 2011. "R: A language and environment for statistical computing." R Foundation for Statistical Computing, Vienna, Austria.

Robinson, Jonathan. 2005. "Desertification and disarray: The threats to plant genetic resources of southern Darfur, western Sudan." *Plant Genetic Resources: Characterization And Utilization* 3 (1): 3–11.

Senft, R. L., M. B. Coughenour, D. W. Bailey, L. R. Rittenhouse, O. E. Sala, and D. M. Swift. 1987. "Large herbivore foraging and ecological hierarchies." *BioScience* 37 (11): 789–799.

Sharawi, Huda Abdelwahab, and Abdelaziz Karamalla Gaiballa. 2010. "The socioeconomic aspects of natural resource management." The Federal Ministry of Agriculture and Forestry, Western Sudan Resources Management Program (WSRMP), IFAD.

Simmons, A. J., K. M. Willett, P. D. Jones, P. W. Thorne, and D. P. Dee. 2010. "Low-frequency variations in surface atmospheric humidity, temperature, and precipitation: Inferences from reanalyses and monthly gridded observational data sets." *Journal of Geophysical Research* 115.

Sulieman, Hussein. 2013. "Land grabbing along livestock migration routes, Gedarif State, Sudan."

Takana, Yousif. 2008. "The politics of local boundaries and conflict in Sudan: The South Darfur case." Sudan working paper 2008: 2. Chr. Michelsen Institute (CMI).

Takana, Y., A. Rahim, and A. H. E. M. Adam. 2012. "Darfur pastoralists groups: New opportunities for change and peace building." Pastoralism policy working paper series. Khartoum: Feinstein International Center, Tufts University Friedman School of Nutrition Science and Policy and United Nations Environment Programme.

UNEP. 2007. "Sudan, post-conflict environmental assessment." Nairobi: United Nations Environment Programme.

Van Dyne, G. M., N. R. Brockington, Z. Szocs, J. Duek, C. A. Ribic, and A. I. Breymeyer. 1980. "Large herbivore subsystem." In *Grasslands, systems analysis and man*, 269–537. Cambridge: Cambridge University Press.

White, R. G. 1983. "Foraging patterns and their multiplier effects on productivity of northern ungulates." *Oikos* 40 (3): 377–384.

Wilson, R. T., and S. E. Clarke. 1976. "Studies on the livestock of Southern Darfur, Sudan II. Production traits in cattle." *Tropical Animal Health Production* 8:47–51.

Young, Helen, and Z. Cormack. 2013. "A policy review on pastoralism in Sudan: An introduction to the working paper series." Pastoralism policy working paper series. Khartoum: Feinstein International Center, Tufts University Friedman School of Nutrition Science and Policy and United Nations Environment Programme.

Young, Helen, Hussein Sulieman, Roy Behnke, Zoe Cormack, Abdelhafiz Mohamed Adam, Samira Mohammed Ahmed, and Hamid Mohamed Abdelnabi. 2013. "Pastoralism in practice: Monitoring livestock mobility in contemporary Sudan." United Nations Environment Programme.

Acronyms

ABS	Acrylonitrile Butadiene Styrene (plastic)
CV	Coefficient of Variation
ECMWF	European Centre for Medium-Range Weather Forecasts
GDP	Gross Domestic Product
GPCC	Global Precipitation Climatology Centre
NDVI	Normalized Difference Vegetation Index
NGO	Non-governmental Organization
SIEP	Sudan Integrated Environment Programme
SDG	Sudanese Pound
SSP	South Sudanese Pound
UNAMID	United Nations–African Union Mission in Darfur
UNEP	United Nations Environment Programme
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
UTC	Coordinated Universal Time

Glossary

ajawid	local committee for negotiating disputes, especially involving livestock
Atmur	local term given to the area north of Totoloto in East Darfur that is suitable for cultivation and does not seasonally flood
Baggara	term applied to cattle pastoralists in western Sudan, and also to the type of Sudan Zebu cattle, known as Western Sudan Baggara (Abdel Rahman 2007).
Bahr	river (also the local term for the pastoralist grazing area in the vicinity of the Bahr el Arab)
Boroya	local term given to pasturelands in the East Darfur southern frontier
Butha	local term given to the pasturelands south of the Boroya that provide year-round water and forage
dahal/ duhuul (pl.)	big pond formed within a riverbed when the river currents have reduced or ceased
Dahara	high ground (also the term for the region to the north of the Bahr)
daranga	traditional bed
deret	end of rains
dhamin	guarantor
diya	payment or blood money
donki/ dwanki (pl.)	water yard (motorized water station) consisting of a deep well connected to a mechanized pumping station and water storage tank
edd/edad (pl.)	shallow-dug well in river beds or close to permanent water sources
farig	temporary pastoralist camp
fawa	large, flat depression with very tall grass and no trees, an important grazing resource in the Bahr
Goz	local term to describe rolling, stabilized dunes (also the local term for the pastoralist grazing zone to the north of East Darfur)
hafir	seasonal water reserve
khalwa	preschool, for teaching the Holy Koran
kharif	rainy season
kornaca	nut kernel

lalob	fruit from the *heglig* tree (desert date, *Balanites aegyptiaca*)
legna shabi	popular committee or panel
nazir	tribal leader (senior administrative level)
omda	tribal leader (middle administrative level)
ragaba/ rugab (pl.)	area where rainwater collects and remains as a pool during or after the rains; also applies to the area once surface water has dried up
rahad/ ruhuud (pl.)	pool of rainwater that collects in natural depressions
rushash	onset of the rains
seif	hot dry season
sheikh	tribal leader (local administrative level)
shita	cold dry season
shukabah	floor mat
wakil	deputy nazir
zariba al hawa	air enclosure (a fenced-off area for livestock grazing, constructed with branches from thorn trees, thus allowing the wind to pass through)

Annexes

Annex 1. Characteristics of the two GPS tagging devices

	Microtrax Pathfinder (2013 study)	Snaptrax (2015 study)
Company	Skorpa Telemetry	Skorpa Telemetry
Weight	< 90 g, including battery and potting	17 g, including battery and potting
Measurement of the potted device	3 x 5 x 2.5 cm	4.5 x 2.5 x 4.0 cm
Hermetically sealed, water- and dustproof	Yes	Yes, encased in ABS plastic
Maximum battery life	4 months	9 months
External light	Yes	No
Frequency of readings	Every 5 minutes	3 consecutive snaps every 15 minutes
Wire connection for downloading data	Water/dustproof slot for wire transfer	Small multi-pinned plug, sealed with putty
Data downloading time and battery charging		Usually 8 to 10 hours, but some times up to 16 hours
Downloading software	GPS Viewer (from Skorpa)	Robin GPS Logger System (Anon. 2013; Mendzylewski 2013)
Data decoding (over the internet)	Not applicable	Usually 8 to 10 hours; if internet connections are good, this can coincide with downloading
Other features		Small external "patch" antenna
Malfunctions	Severe damage to the outer casings of some devices, exposing the battery and rendering it unstable. Despite programming the devices to take readings every five minutes, the devices were faulty and took readings much more frequently, thus decreasing battery life significantly.	The sealed plug of 1 of the 9 devices became blocked, but with careful cleaning a connection could be made.

Annex 2. List of grasses, shrubs, and trees identified as fodder sources by pastoralists in the 2013 longitudinal study

G = Grass; H = Herb; T = Tree; S = Shrub; T/S = Tree or Shrub
ED = East Darfur; NK = North Kordofan

List of grasses and herbs

Local name	ED or NK	Latin name	Life form	Arabic
Abu Asabee	NK	*Dactyloctenium aegyptium*	G	أبو اصابع
Abu Jigrah	ED	*Brachariaxantholeuca*	G	أبوجيقيرة
Abu Rakhees	NK	*Andropogon spp.*	G	أبورخيص
Abu Silialah	ED/NK	*Aristida mutablis*	G	سلعلع
Adar	ED/NK	*Sorghum halepense*	G	عدار
Albayadh	NK	*Aneilema lanceolatum (or Aristida)*	H	البيض
Aldahasser	NK	*Indigofera semitrijuga*	H	دهاسير
Aada	NK	*Geigeria alata*	H	قدقاد
Arkasi	NK	*Chrozophora spp.*	H	أرقسى
Benu	ED/NK	*Eragrostis sp.*	G	بنو
Berdy	ED	*Echinochloa stagnina*	G	بردى
Deresa	ED/NK	*Tribulus terrestris (thorny grass seed)*	H	ضريسة
Defrra	NK	*Echinochloa colonum*	G	دفرة
Edeinat Alfar	NK	*Requenia obcordata*	H	أضان الفار
Folah	ED/NK	*Echinochloa*	G	فولة
Gaw	ED/NK	*Aristida spp. (adscensionis)*	G	قو
Hantoot	NK	*Ipomoea blepharosepala*	H	حنتوت
Haskaneet	NK	*Cenchrus biflorus*	G	حسكنيتخشن
Keraeb	ED/NK	*Brachiaria xantholeuca*	G	كوريب
Kordalah	ED	*Maerua pseudopetalosa*	H	كردالة
Liseag	ED/NK	*Setaria verticillata*	G	لصيق
Malhee	NK	*Sporobolus microprotus*	G	أبو مالح
Om Ger	ED/NK	*Brachiaria obtusiflora*	G	أم جر
Om Hadeed	ED/NK	*Echinocloa frumentacea*	G	أم حديدة
Om Mefreta	NK	*Schoenefoldia gracils*	G	أم مفيريطة
Raba	NK	*Trianthema pentandra*	H	ربعة

Shara	ED/NK	*Indigofera semitrijuga*	H	شرايا
Shelinee	NK	*Zorniadiphylla*	H	شيليني
Tibin	ED	*Oryza longistaminata*	G	تبن
Tokah	NK	*Cyprus conglomeratus*	G	أم تك
Al Khushein	NK		G	الخشين
Al Oram	NK		G	العرام
Boose	ED		G	
Om Fukhaya	ED		G	
Om Karalow	ED		G	
Tabar	NK		G	
Gutp	NK		G	
Demblab	NK		H	الدمبلاب
El Mardo	ED		G	
(39 species of grasses and herbs in total, 9 unidentified)				

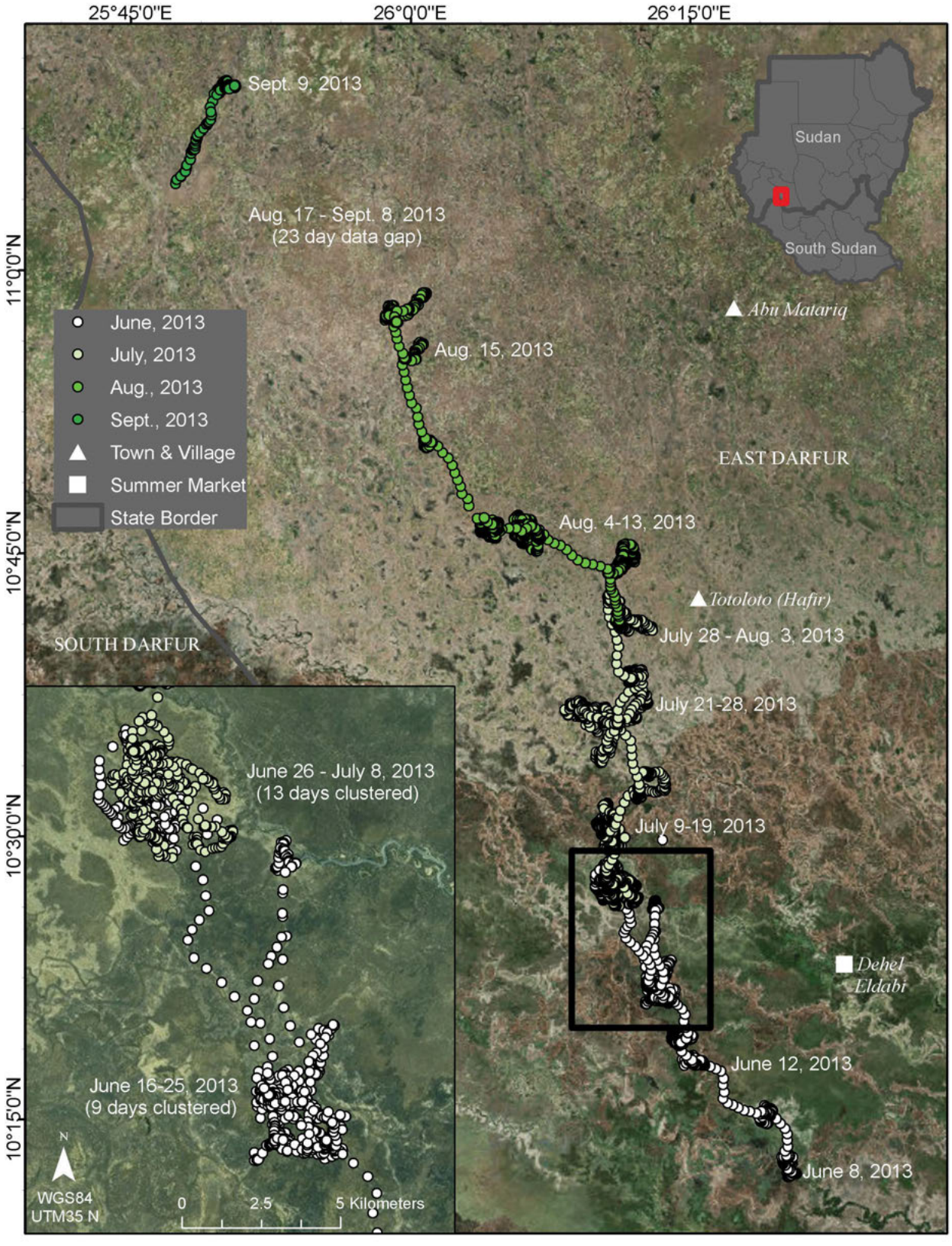
List of shrubs and trees

Local name	ED or NK	Latin	Life form	Arabic
Alishoop	NK	*Grewia flavescens*	S	شوب
Andrab	ED/NK	*Cordia rothii*	T	إندراب
Arad	NK	*Albizia amara subsp. sericocephala*	T	عرد
Aradeb (fruit)	NK	*Tamarindus indica*	T	عرديب
Gafel	NK	*Commiphora africana*	T	قفل
Gebesh	NK	*Guiera senegalensis*	T	غبيش
Gidem (fruit)	ED/NK	*Grewia tenax*	S	قضيم
Gughan	NK	*Diospyros mespiliformis*	T	جوغان
Habeel	NK	*Combretum glutinosum*	T	هبيل
Haraz	NK	*Acacia albida*	T	حراز
Hashab	NK	*Acacia senegal*	T	هشاب
Heglig (Lalob fruit)	NK	*Balanites aegyptiaca*	T	هجليج
Hemaid	NK	*Sclerocarya birrea*	T	حميض
Kadad	NK	*Dicharostachys glomerata*	S	كداد
Kafoor	NK	*Eucalyptus aegyptiaca*	T	كافور

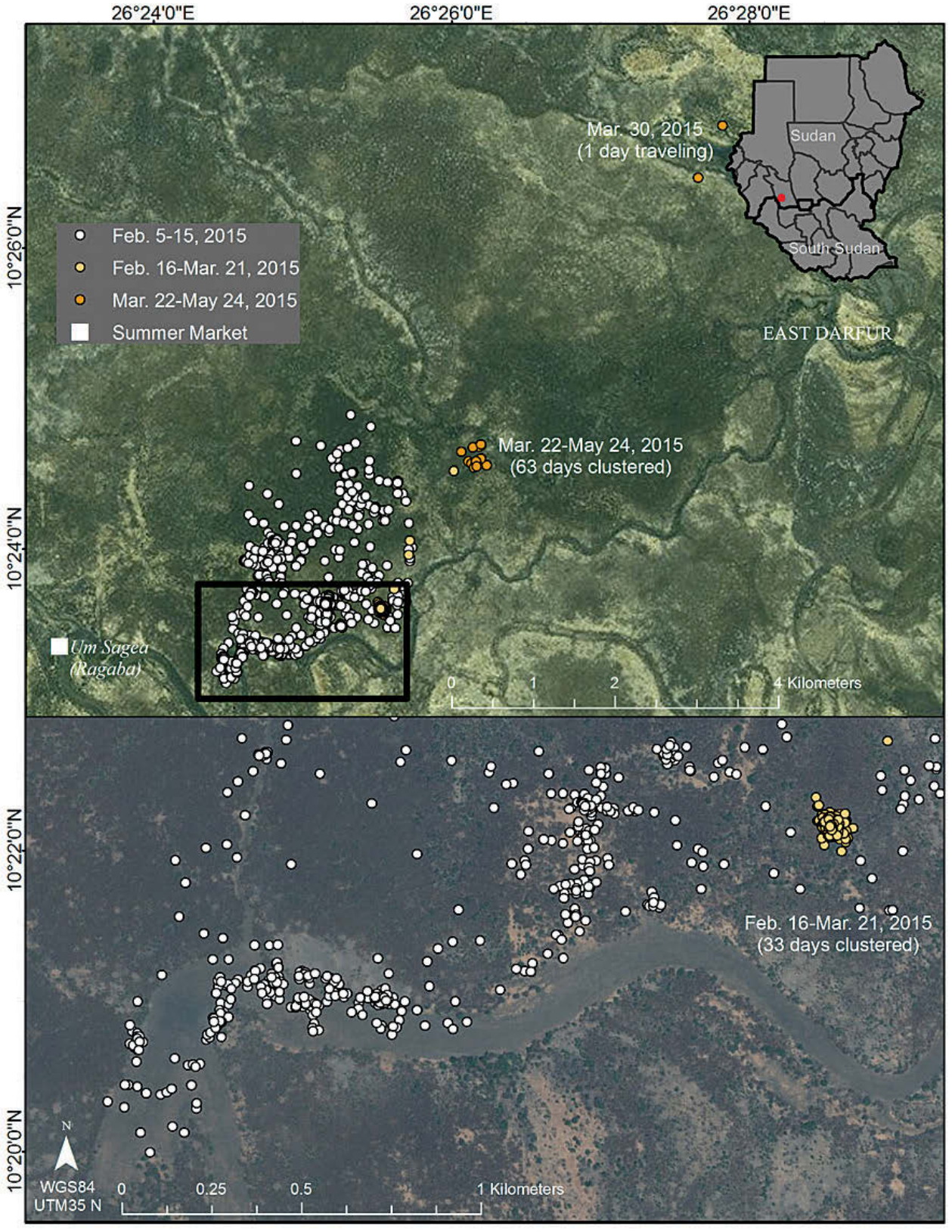
Kitr	NK	*Acacia mellifera*	T	كتر
Kook	ED	*Acacia seiberiana*	T	كوك
Kursan	NK	*Boscia senegalensis*	T/S	كرسان
Laot	NK	*Acacianubica*	T	لعوت
Layoun	NK	*Lannea humills*	T	ليون
Marikh	NK	*Leptadenia pyrotechnica*	T/S	مرخ
Mukheit	NK	*Bosciasenegalensis*	T/S	مخيط
Om Heamaroona	ED/NK	*Hymenocardia acida*	T/S	أم حميرون
Om Hibuloh	ED	*Combretumglutinosum*	T	أم هبيلو
Om Siniena	NK	*Acacia polyacantha subsp. campylacantha*	T	أم سنينة
Oshar	NK	*Calotrophis procera*	S	عشر
Saljem	NK	*Acacia gerrardii var. gerrardii*	T	سلجم
Sedr	NK	*Ziziphus spina–cristi*	T	سدر
Sereh	ED/NK	*Cadaba farinosa*	T/S	سرح
Seyal	NK	*Acacia tortilis subsp. radiana*	T	سيال
Shikheat	NK	*Combretum aculeatum*	T	الشحيط
Subagh	NK	*Terminaliabrowni*	T	صباغ
Sunt	NK	*Acacia nilotica subsp. Adansonii or Acacia Arabica**	T	سنط
Taleh	NK	*Acacia seyal var. seyal*	T	طلح أحمر
Tondob	NK	*Capparis decidua*	T	طندب
Kadak	ED	*	T	
Somr	NK	*Acacia tortellis*	T	
(37 tree and shrub species in total, 2 unidentified(*))				

Annex 3. Maps of livestock mobility in 2015 (maps that do not appear in main report)

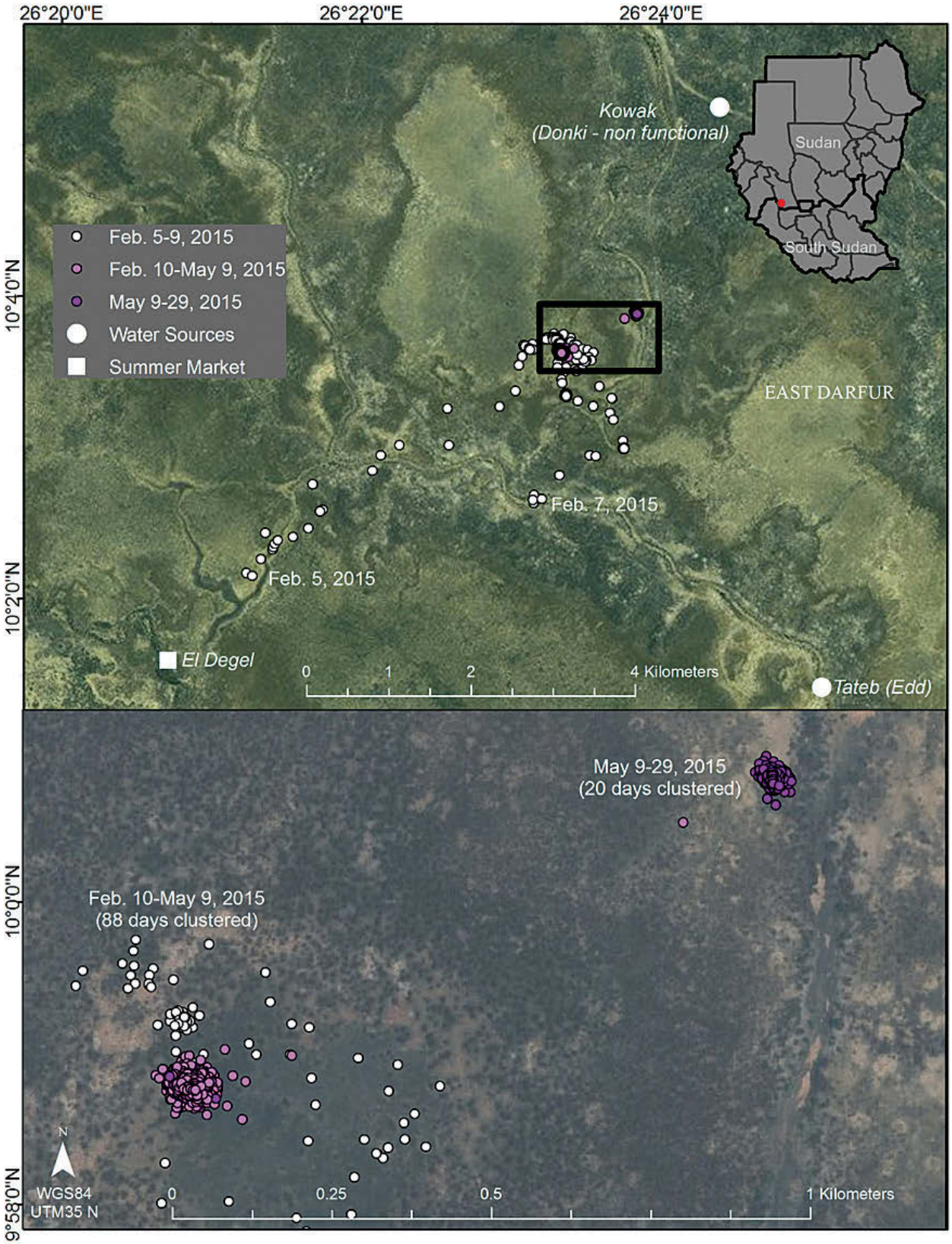
1. Migration north by Pastoralist 3 Cattle, 2013.



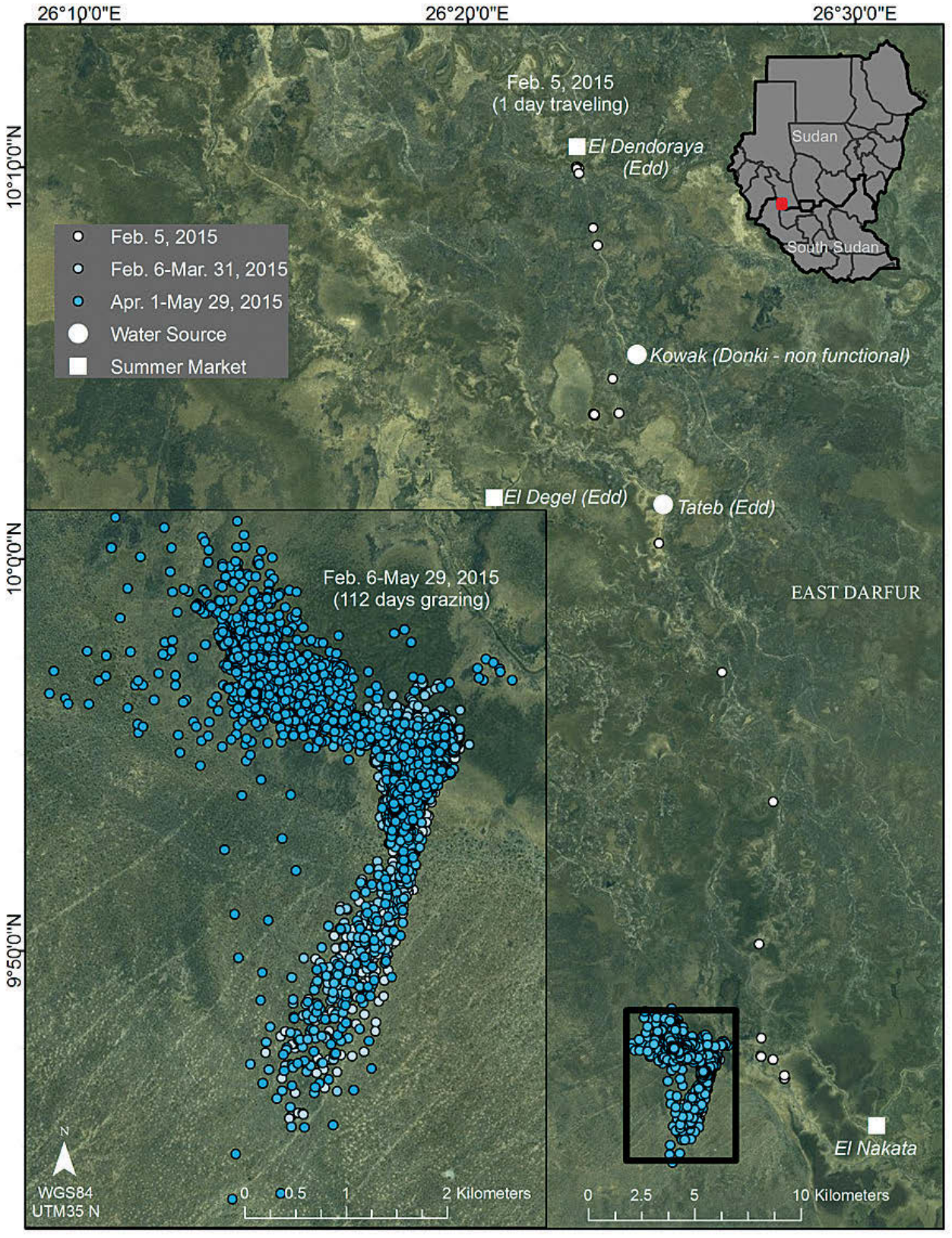
2. Dry season grazing patterns of Pastoralist 1 cattle, 2015



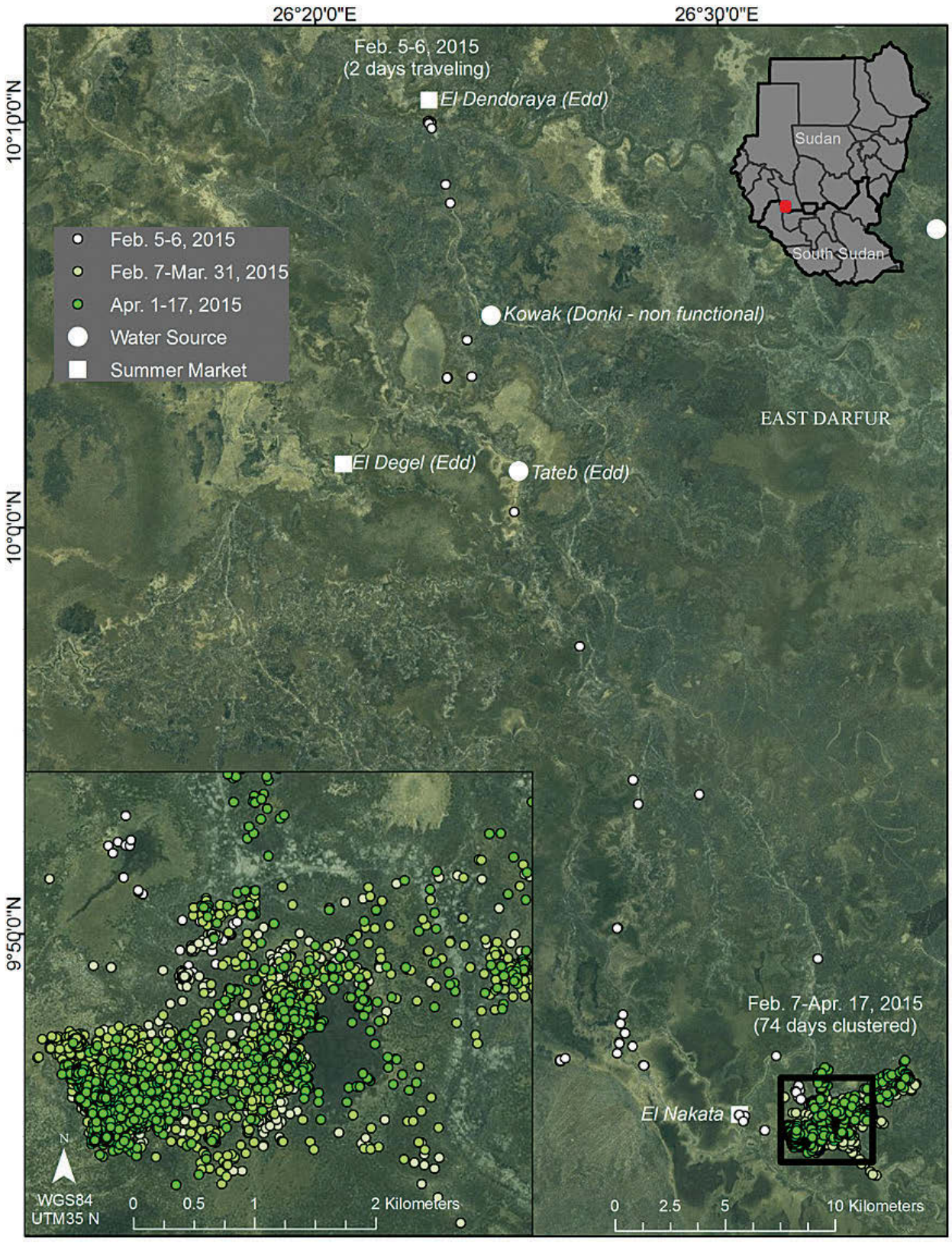
3. Dry season grazing patterns of Pastoralist 3 cattle, 2015



4. Dry season grazing patterns of Pastoralist 4 cattle, 2015



5. Dry season grazing patterns of Pastoralist 6 cattle, 2015



Feinstein International Center

Feinstein International Center
Tufts University
114 Curtis Street
Somerville, MA 02144
USA
tel: +1 617.627.3423
fax: +1 617.627.3428
fic.tufts.edu