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Seasonal distribution of livestock in Samburu county, northern Kenya: a response to variable pasture and water in semi-arid rangelands

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Spatial and temporal climate variability dictate herd mobility of transhumant communities, and therefore understanding this interrelationship is key to sustainable management of rangelands, especially in the face of the changing climate. This study was undertaken in Samburu county in Kenya, an area characterised by varying climatic conditions, land uses and agro-ecological zones, to determine the interrelationship between rainfall and temperature variability and the mobility of herds. To achieve the research objectives, 20 years of data for temperature, rainfall, normalised difference vegetation index (NDVI) and georeferenced data (GIS) together with field data obtained through household interviews and community participatory mapping were utilised. Only Samburu Central is endowed with good rainfall and the pastoralists graze their animals around their homes all year round. Rarely does livestock in Samburu East graze around homesteads due to low rainfall and degraded pastures. The spatial distribution patterns of the herds followed pasture availability as shown by vegetation NDVI patterns. Areas with higher NDVI of over 0.3 attracted herd concentration but with high *in situ* mobility to maximise on grazing of the most nutritious pastures. This study proposes grazing management embedded in observed herd mobility and grazing resource use patterns as a strategy towards adapting the pastoral communities to the changing climate.

Keywords: herd mobility, participatory mapping, pastoralism, seasonal grazing patterns

Introduction

Pastoralism is the practice of animal husbandry involving mobility of herds in time and space across expansive areas in search of scarce and highly variable grazing and water resources in the rangelands (MacOpiyo 2005). The practice of livestock husbandry by pastoralists (who inhabit at least half of the earth's surface) enables utilisation of the world's areas less favourable for agriculture, which are characterised by extreme climatic conditions, as well as variability and uncertainty in climatic conditions (Galaty and Johnson 1990; ILRI et al. 2021). In northern Kenya, particularly in Samburu county, pastoral mobility has been documented as the most effective strategy to make use of variable resources, making mobile pastoralism a highly valued strategy in the management of grazing areas and exploitation of variable resources (Pas-Schrijver 2019). In Africa, rangelands are water-limited ecosystems that largely occupy arid and semi-arid (ASAL) areas, and which support more than one-third of Africa's population (Adriansen 1999). The rangelands contribute to national, regional and world economic development by supporting livestock production opportunities, which in turn uphold the ends of sustainable development goals (SDGs), carbon sequestration and wildlife conservation; the promotion of tourism; and the sustaining and protection of culture (Mulianga 2009; Timpong-Jones et al. 2023).

In order to replace nomadic pastoralism and promote settled agriculture in suitable areas, the colonial government established the African Land Development Organisation (ALDEV) in 1945. This organisation created a private enclosure land system where land ownership was firmly based on family holdings (Kibugi 2013). An investigation into land consolidation and registration in Kenya was ordered by the government in 1965. The inquiry report, also known as the Lawrence Report, concluded that group registration of land had greater significance for range areas than individual registration. The Land Adjudication Act and the Land (Group Representatives) Act were subsequently passed by the government to establish a legal framework for defining and regulating group ranches (Wayumba 2004; 2017). Overgrazing and uncontrolled grazing are acknowledged as the two main causes of rangeland degradation. In Samburu, grass predominates on poorly maintained rangelands. Overstocking, unplanned or unregulated grazing, overgrazing and inadequate grazing management techniques have all contributed to the decline of Samburu rangelands over the years (Pas-Schrijver 2019). The degradation of Samburu county's natural grazing lands is primarily the result of shifting land use patterns, including the encroachment of settlements and cultivation into rangelands, partial breakdown of traditional seasonal grazing patterns, reduced mobility of herds as a result of new settlements, loss of the authority of traditional elders and an overabundance of livestock (Lesorogol 2008). Additional contributing causes include climatic changes, such as frequent, protracted droughts and

unpredictable rainfall linked to climate change. Investments in infrastructure, including the Lamu Port–South Sudan–Ethiopia Transport (LAPSSET) corridor have had a large impact on pastoralism in ways that include restricting rights to land and other resources, triggering immigration and intensifying security issues (Lind et al. 2020).

Rangelands cover 80%, 50% and 40% of Kenya, Tanzania and Uganda respectively and have provided livelihoods for millions of pastoralists in East Africa (Fratkin 2001; Orindi et al. 2007; Nyariki et al. 2009). Pastoralists and their herds in these rangelands have traditionally lived harmoniously within their environment. However, increasing human population pressure, extractive market forces, renewable energy projects, afforestation programmes, land privatisation and alienation from the pastoral system have precipitated grazing resource degradation and, increasingly, resource-based conflicts in these areas. This situation is exacerbated by emerging diseases and other factors that pose challenges to access to pasture (Moenga et al. 2016). Climatic variability and change will increase the fluctuations of feed and fodder availability, further amplifying these risks. Moreover, human population pressure has created an increasing demand for livestock products resulting in increasing livestock numbers, and loss of pastoral land to conservation and agriculture has placed constraints on access to feed for pastoral communities (Galvin et al. 2001; Mulianga 2009). The resultant reduced space restricts seasonal mobility of pastoralists' herds and prevents them from exploiting resources that vary spatially and temporally across the landscapes – as dictated by both natural and climatic factors of the production system (Adriansen 1999; Mulianga 2009; Lengoiboni 2011). Such mobility could either be regular and limited to short distances or irregular, which involves large-scale and trans-boundary movements, depending upon socio-economic, climatic and environmental factors (MacOpiyo 2005; Samuels et al. 2019).

Besides factors such as population growth, changes in land use and the effects of drought, environmental and socio-economic factors are giving rise to negative trends that pose a threat to the livelihoods of the pastoral community (Michael 2017), leading pastoralists to explore alternative livelihoods (Catley et al. 2016). Environmental factors include increased variability of rain days and extreme weather events, and increases in the incidences of disease (Kitasho et al. 2020). Vulnerability of pastoralists calls for development of a set of actions aimed towards enabling them to adapt to the changing climate (Eriksen and Marin 2011). The current adaptation practices employed by pastoralists include livestock destocking, livestock species diversification, migration and livelihood diversification, such as growing fodder grass and engaging in petty trade (Berhanu and Beyene 2015; Cuni-Sanchez et al. 2019; Kitasho et al. 2020).

ASAL rangelands in East Africa experience two dry seasons (July to September and January to March), alternating with two rainfall seasons. The long rains mostly occur during April, May and June and the short rains during October, November and December (Mutai and Ward 2000; Galvin et al. 2001). In Kenya, mobility usually occurs as the dry seasons set in. During these periods, pastoralists follow seasonal routes as dictated by pasture and water availability. While dependent on the method of analysis used, mobility patterns among the pastoralists was seen as both unpredictable yet regular and orderly (McCabe 2010). As the pastoralists move, they face various challenges such as competition over resources leading to resource-based conflicts, livestock diseases and predation from wild cats (Blench 2000; Moenga et al. 2016). Cases of livestock disease are presumably higher in the dry season because veterinary services in dry-season grazing areas are limited or non-existent (Cowled and Garner 2008; Bayissa et al. 2009; Nkedianye et al. 2011). At the same time, livestock from all the pastoral communities converge in such areas, hence the risk of spreading of diseases. Low-potential rangelands, which account for 77.5% of total land surface area in Samburu county, are primarily located in the Waso, Wamba and Nyiro areas, where land is controlled under communal and ranch tenure systems. Nomadic pastoralism dominates land use in these rangelands. The county has roughly 140 900 hectares (7%) of medium to prospective agricultural land. This area is located in the Kirisia and Lorroki areas, which receive 600–900 mm of rainfall each year. Approximately 6 000 ha are currently cultivated and planted with wheat, barley, maize, beans, and a variety of fruits and vegetables. Nomadic pastoralism dominates land use in the lowland rangelands, which account for 77.5% of the county total area. Land in the rangelands is owned by group ranches/communities and will remain so for a long time. The area under cultivation is gradually expanding, and dairy farming is becoming more popular (Samburu County Government 2013, 2018).

Overgrazing and its associated environmental deterioration are a problem with communal land ownership in the rangelands (Zinsstag et al. 2016). As more land is cultivated in the highlands, vegetation cover is reduced and soils are exposed to erosion agents. *Acacia* species dominate the vegetation in the Samburu lowlands, which are mostly covered with bushy and forested grasslands. Heavy grazing in the past and an uneven rainfall distribution have resulted in bush encroachment, making it difficult for cattle to find grazing for most of the year in the area between the Seyia River and Waso Nyiro (Pas-Schrijver 2019). Because it is more difficult for cattle to find grazing in the area, the Samburu have begun to invest in goats and camels, which can browse plants other than grass. Such strategies are designed to deal with climate fluctuation and vegetation changes, but they are not always effective, and may not prevent high animal mortality and starvation among pastoralists during periods of prolonged drought (Nkedienye et al. 2011). Droughts were common in the African dry lands long before climate change was a topic of popular discussion. For example, records show that from 1540 to 1800 the area experienced 26 significant droughts and famines, including the Great Famine of 1889–1892 (Scoones 1995; Niamir-Fuller 1999). Droughts have been observed in East Africa since the Middle Ages, and at least two major droughts occurred in the Sahel in the first half of the 20th century, before the well-publicised Sahelian drought in the late 1960s and early 1970s (Scoones 1995).

Pastoralist production requires access to labour (for herding) as well as important pasture and water resources. Because these resources are dispersed geographically and across the seasons, pastoralist production relies heavily on

livestock mobility. Pastoralists in northern Kenya currently practice semi-nomadic pastoralism, which means that only part of the family, not the entire household, moves the animals to locations with pasture and water.

While drought exerts pressure on the already fragile rangelands, this situation is further exacerbated by floods, resulting in crop failure and livestock death. Epidemics of the late 19th and early 20th centuries, such as rinderpest, resulted in massive cattle (and wildlife) mortality and human suffering (Bizimana 1994). Cropping expansion into pastoral areas is displacing the greatest dry-season pastures in several countries (Lesorogol 2008). Due to the changing climate patterns, some of the pastoralists have turned to farming. This has brought about resource-based conflicts due to land use changes as evidence suggests that the conflicts increase during the wet seasons and are concentrated around agricultural lands (McGuirk and Nunn 2020). In addition, invasive plants such as *Prosopis* and *Sansevieria* species, which are increasingly common, are decreasing grass growth. Further access to pastures is frequently hampered by resource use conflicts, disease outbreaks and related trade bans, as well as population expansion and a corresponding fall in the average herd size (the number of animals per person), to a level below subsistence. This diminishes income and viability of pastoral production.

Despite these challenges and the continued loss of animals, little or no attention has been directed towards finding solutions to pastoralism-related challenges. Particularly, the nexus between climate variability and herd mobility has not been adequately analysed in Samburu county to spur resource planning in order to ensure utilisation of rangeland resources in a sustainable manner. It is through the understanding of the relationship between temperature and rainfall variability and herd mobility that proper planning and management of rangelands can be achieved. While Sperling (1987) conducted a study in Samburu that describes the labour requirements for herding during herd mobility, data are lacking on herd mobility trends, herd distribution in space and time, transhumance, and the relationship between herd mobility and climate variability. This study investigated the patterns of herd mobility and resource use and its relationship with climate variability through analysis of herd distributions during different seasons of the year. The study aimed at proposing interventions and strategies for northern Kenya that will ensure that climate variability and herd mobility do not further increase constraints on livestock production.

Materials and methods

Study area

This study was carried out in six sub-locations of Samburu county (Figure 1). Samburu covers an area of approximately 21 022 km^2. It is a semi-arid rangeland which lies between latitude of 00°30′ N–2°45′ N and longitude of 36°15′–38°10′ E, with elevation averaging approximately 900 m above sea level (Samburu County Government 2018). It borders Baringo and Turkana counties to the west, Marsabit county to the north, Isiolo county to the east and Laikipia county to the south. The county is divided physiographically into the following major units: Leroghi plateau, which rises to over 2 000 m, Nyiru and Ndoto mountains and Matthews Range, with elevation ranging between 1 500 and 2 500 m (Samburu County Government and WFP 2015). The county also includes the eastern flank of the Great Rift Valley and the plains sloping towards Lake Turkana, Isiolo and Marsabit, ranging in elevation between 1 000 and 1 350 m.

The climate of the county varies with altitude. The average annual rainfall ranges from below 400 mm in the lowlands to above 1 250 mm in the mountains (Samburu County Government and WFP 2015). The driest months are January to March. The long rainy season occurs between November and December but some rains are experienced during other months especially in May/June. Potential annual evaporation in Samburu is a function of altitude and it ranges from 500 mm to 1 200 mm per annum (Samburu County Government and WFP 2015). Temperature ranges from 24 °C to 36 °C. Only 8% of the county is classified as high rainfall area with adequate moisture to support arable agriculture, while the rest (92%) is classified as rangelands. The climate can be described as dry lowland equatorial climate. Rainfall patterns follow a very unpredictable pattern which varies very significantly in time and space.

Samburu county is categorised into lower highlands zone, upper midland, lower midlands zone, intermediate lowlands and indistinct zones/transitional ecological zones (Samburu County Government 2013, 2018; Samburu County Government and WFP 2015). The vegetation in the study area can be described as evergreen forests, evergreen bush land to dry semi-deciduous bush land/thicket and grasslands. The main trees and shrub species include: *Vachellia tortilis, Senegalia senegal, Boscia angustifolia, Salvadora persica, Cordia sinensis, Croton dichogamus, Psiadia punctulata.* Grasses comprise *Themeda triandra, Cenchrus ciliaris, Eragrostis superba.* Wild animals in Samburu include *Panthera leo* (lion), *Phacochoerus africanus* (warthog), *Crocuta crocuta* (hyena), *Loxodonta africana* (elephant), *Gazella* spp. (gazelles), *Antilopinae* spp. (antelopes), *Equus* spp. (zebras) and various avian spp. (birds) (Samburu County Government 2013, 2018).

Selection of the study sites

This research utilised an explanatory multiple-case study design. The case study approach was utilised to understand interrelationships between climate variability, herd mobility and resource use patterns in the day to day life of a pastoralist (Yin 1994, 2014; Zainal 2007). The pastoral communities of Ngutuk Engiron, Lpus, Swari, Lonyangaten and Arsim sub-locations, and the agropastoral community of Longewan sub-location (Figure 1) were used as case studies in this study. The sub-locations were selected based on: representativeness of livelihood zones; areas prone to drought shocks hence experiencing herd mobility; and other neighbouring counties hence allowing cross-border herd mobility.

The sub-locations were selected from the six wards (Suguta Marmar, Wamba West, Waso, Wamba North, Ndoto and Elbarta) in Samburu county, which border other counties hence allowing cross-border herd mobility. Therefore, in this case Samburu county acted as an epicentre for herd mobility.

Permission was requested from the concerned national and county government offices before embarking on the data collection for this research. As an ethical requirement

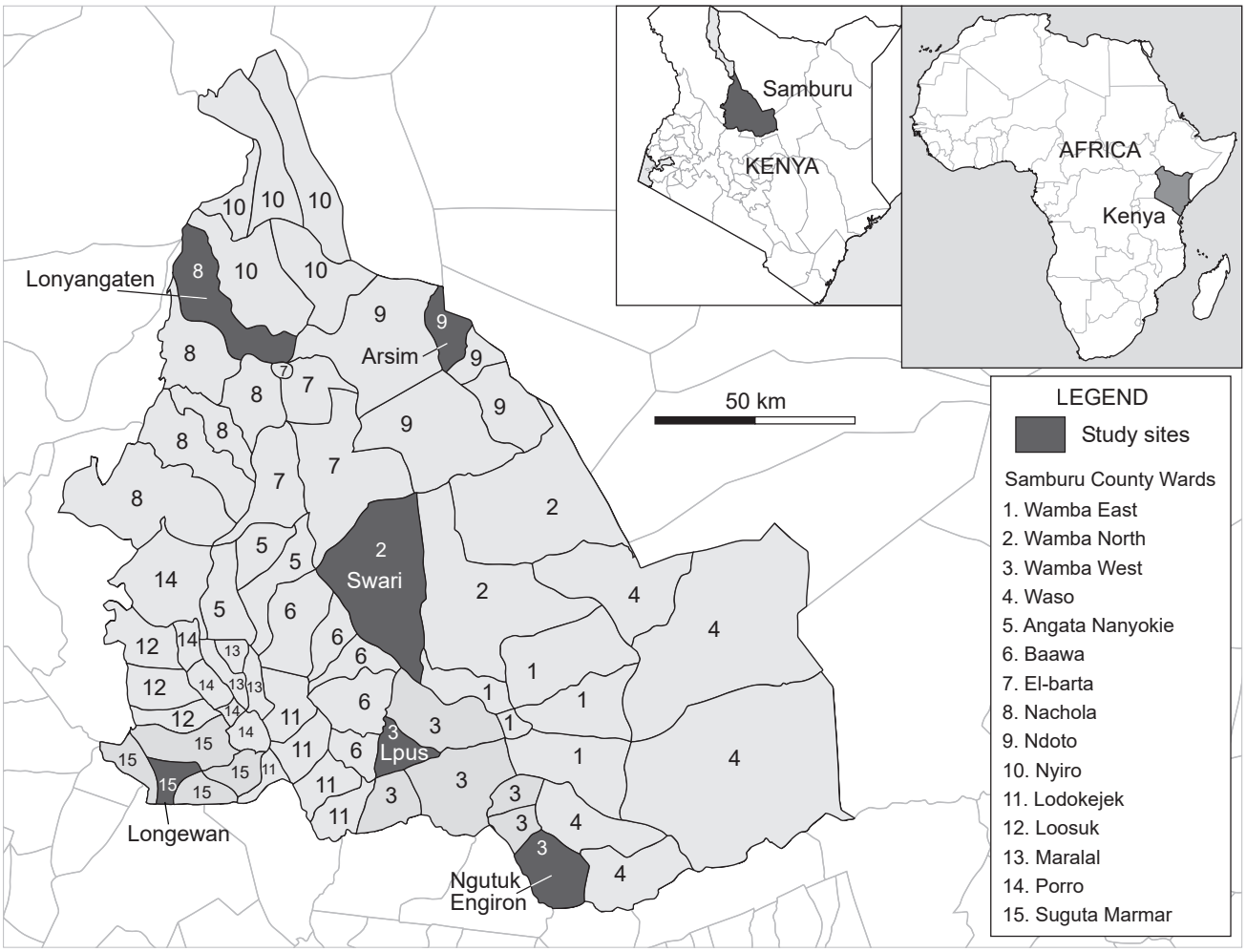

Figure 1: Study sites

for any study involving human elements, the researchers and the enumerators sought consent of the targeted participants and let them know the purpose of the research before starting the interview sessions. This research was licensed by the National Commission for Science, Technology and Innovation in Kenya under license number NACOSTI/P/22/15712.

Data collection

Participatory herd mobility mapping

Participatory mapping was used to investigate the timing and routes used for seasonal migrations by translating the information obtained onto a map. Participatory mapping usually involves the respondents discussing and agreeing on the mobility routes (Lengoiboni 2011), especially with regards to areas they frequent in search of pasture during droughts and how often they use those routes. This knowledge has been acquired by the pastoralists through the seasons and in a spatial–temporal context. Although herd mobility patterns can easily be generated using other GIS-based methods, well-informed, comprehensive and reliable patterns demand much input from the pastoralists themselves. Participatory mapping is a visualisation tool that helps to appreciate key livestock infrastructure, social amenities, stock routes and livestock disease hotspots/entry points (Chambers 2006). Probing the maps helped to appreciate the dry season grazing zones, resource-based conflict zones, and the association between seasonality, livestock migration, intercommunity conflict and livestock health events.

In order to ensure that the desired data on herd mobility was obtained, a participatory mapping exercise was conducted per study site (comprising all age categories and both male and female respondents) of between 5 and 10 participants aged between 22 and 70 years) with knowledge and experience in herd mobility, selected purposively through the assistance of local leaders. In the course of the discussion, validation of the mobility patterns resulting from the literature review and other sources was done. Mapping sessions were conducted with one focus group per study site. During this exercise, the participants drew maps on flip charts with information regarding the study site (roads, towns, forests, surrounding group ranches and private ranches). The drawn maps were then used in the participatory mapping exercise. The respondents were required to identify the location of their homesteads (*manyattas)*, topographic

features, dry season and wet season herding areas and to categorise the identified grazing areas with respect to the resources that are found there and how they can be accessed. The participants further drew the livestock mobility sequence during the different seasons of the year. The actual livestock mobility patterns were discussed, agreed and approved by the group members themselves. Further probing was done to confirm any changes between current herd mobility patterns and those in the past (up to 20 years ago). Any differences were captured in these maps and the reasons for the changes probed and noted in the research findings. The information on these maps with the migratory route areas was then transferred and analysed using ArcMap 10.8 software.

Distribution of herds in time and space was generated from both the participatory mapping exercise and the household survey. Each household respondent was asked to mention where his or her animals grazed from January to March, April to June, July to September and October to December. For this purpose, the livestock from each household was presumed to be one herd and therefore each household questionnaire response with regard to herd mobility referred to a single herd. In the analysed map, the concentrations of livestock in an area therefore represented animals having moved from the respective households to those areas. The actual location data for the herds was therefore obtained using the household surveys.

Household survey

During the study, the pastoralists from the six study sites were interviewed. A total of 347 household interviews were conducted, targeting household heads. The questionnaire covered several topics with regard to herd mobility and climate variability, including locations moved to during different seasons of the year, rainfall characteristics, factors influencing the decision on where to move the animals, climatic trends and pests, and livestock health and services used.

Acquisition and analysis of NDVI data

Monthly decadal normalised difference vegetation index (NDVI) data were acquired from the United States Geological Society (USGS) Early Warning Explorer (EWX) software (https://earlywarning.usgs.gov/fews/ewx/index.html?region=af) for 2002 to 2020. The NDVI analysis was conducted to: (1) provide descriptions of how plant life cycles (phenology), as influenced by climate and habitat variables, change over space and time; and (2) examine the relationship between NDVI values and herd mobility. Seasonal profiles of mean quarterly (3 months) NDVI were analysed and compared across the 15 wards of Samburu county. The quarters are January–March, April–June, July–September and October–December. To investigate the relationship between the changing vegetation and livestock movements, mean quarterly NDVI values were calculated for the actual area occupied by the herd for each quarter.

Precipitation and temperature data

Monthly precipitation and temperature data were acquired from USGS-EWX for 2002 to 2020. Monthly temperature and rainfall data were also acquired from the Kenya Meteorological Department for the period 1981 to 2020 for the six study locations. These data were used to evaluate the climate trends and variability in Samburu county.

Data analysis

Rainfall and temperature data were analysed using MS Excel spreadsheets to determine seasonal and annual variability. Line charts and graphs were used to show rainfall and temperature variability over time showing the trends of annual rainfall over the past 40 years (1981 to 2020).

The availability of pasture in time and space was computed through analysing the herd mobility patterns and computation of NDVI values. The herd numbers in various areas during different seasons (obtained from the household survey and participatory mapping) were recorded in Excel spreadsheets with one column indicating the wards and the other showing the herd numbers. This was then imported into ArcMap 10.8 software and overlaid with administrative polygons (wards). The spatial distribution of livestock was then mapped and the colour graduated symbols option used to develop the ward-level livestock distribution maps during various seasons. Livestock spatial distribution patterns were indicated using a cluster of dots depending on the number of households that moved their livestock to those particular locations. NDVI values maps were generated in ArcMap 10.8 and superimposed with the layers of livestock spatial distribution. Quarterly rainfall averages maps were also generated in ArcMap 10.8 and superimposed with the layers of livestock spatial distribution during analysis of the relationship between herd mobility and rainfall patterns. Where the rainfall or NDVI data were missing, the areas were left blank in the maps without any colour shading. These were mainly areas outside the county. Other factors that dictate herd mobility patterns including availability of pasture, water, salt licks and resource-based conflict situations were also assessed.

Results

Seasonality of rainfall in Samburu county

Quarterly rainfall seasonality analysis (2000 to 2018) revealed that during the first quarter (Q1, January–March), all 15 wards of Samburu county received low rainfall. During the second quarter (Q2, April–June) all the wards received higher rainfall. But in the third quarter (Q3, July–September), rainfall was low (7–40 mm), especially in the lowlands of Samburu including Wamba East, West and North, Waso, El-Barta, Nachola, Ndoto and Nyiro. Conversely, Angata Nanyokie, Baawa, Lodokejek, Loosuk, Maralal, Poro and Suguta Marmar received more rains of between 69 and 142 mm. The fourth quarter of the year (Q4) received rainfall which was slightly more in the lowlands of Samburu East (136–160 mm) than the highland areas of Samburu Central (116–137 mm). Figure 2 provides a detailed analysis of the seasonal trends of rainfall. In the first three quarters of the year, more rainfall was experienced in the highlands of Samburu than in the lowlands, but in the fourth quarter, the lowland areas received more rains than the highlands.

An analysis of the annual trends of the rainfall between 1981 to 2020 (Figure 3) showed a general decline in rainfall amounts in Samburu North (Lonyangaten and Arsim) and a general increase in the rainfall amounts received in Samburu

Central (Longewan) and Samburu East (Swari, Lpus and Ngutuk Engiron).

Factors determining direction and time of pastoralist movements

Pasture availability was the most important factor that determined when and where the pastoralists moved their herds according to all of the household respondents (100%). Water availability was second (97.4%) followed by vulnerability of the area to resource-based conflicts (82.9%), availability of natural salt licks in the area (79.4%), species of livestock kept (79.1%) and emergence of livestock diseases (72.8%) (Table 1). Most of the respondents (64.27%) mentioned livestock keeping as their major occupation while only 1.44% depended on formal employment as a major occupation. Although also practising livestock keeping, most of the respondents (80%) from the Longewan study site in Samburu Central were mainly crop farmers (agropastoralists).

Seasonal herd distribution and grazing patterns

The results show that livestock in the study area migrates from the lowland wet season grazing grounds up to the humid mountain areas in the dry season. In the pastoral zones, that is, predominantly in Samburu North, the main dry season grazing areas are Baragoi, Elbarta, Masikita, Soito and Suyan areas; in Samburu East these areas are Koiting, Lerata, Matakwani, Ngilai, Sesia and Wamba. In Samburu Central, covering part of the agropastoral zone, the dry grazing areas are Ledero, Kisima, Lorroki, Kirimon, Logewani, Lolmolog and Lbukoi. The seasonal distribution patterns are shown in Figure 4.

In Samburu Central, livestock were reported to graze around Kisima, Laikipia, Longewan and Suguta for most the year. Most of the pastoralists in Samburu Central graze around their homes all year round. In the more severe droughts, these pastoralists move their livestock to Laikipia County, especially around Sosian area and they can go as far as Marula and Mount Kenya areas.

In Samburu East, the livestock grazed around Kauro and Kom for most of the year. In the more severe droughts, these pastoralists moved their livestock to the community conservancies, Samburu National Reserve and to the Government National Youth Service (NYS) land in Kirimun. Rarely do livestock in Samburu East (Wamba, Swari, Lodung'okwe and Ngilai) graze around homesteads.

In Samburu North, livestock grazing patterns were mainly dependent on the ethnic community that owns the livestock. Among the Turkana, the animals mainly grazed around the community's territorial boundaries of Nachola, Kawop, Lonyangaten, Terter, Lokorkor and Parkati. The Samburu mainly from Nyiro, Baragoi and Latakweny areas moved their animals to as far as Serolipi and Wamba in Samburu East. In the more severe droughts, the pastoralists from both communities moved their livestock to areas around Samburu North (Marti, Suyan, Morijo and Mbukoi) and in most instances this resulted in resource-based conflicts in these areas.

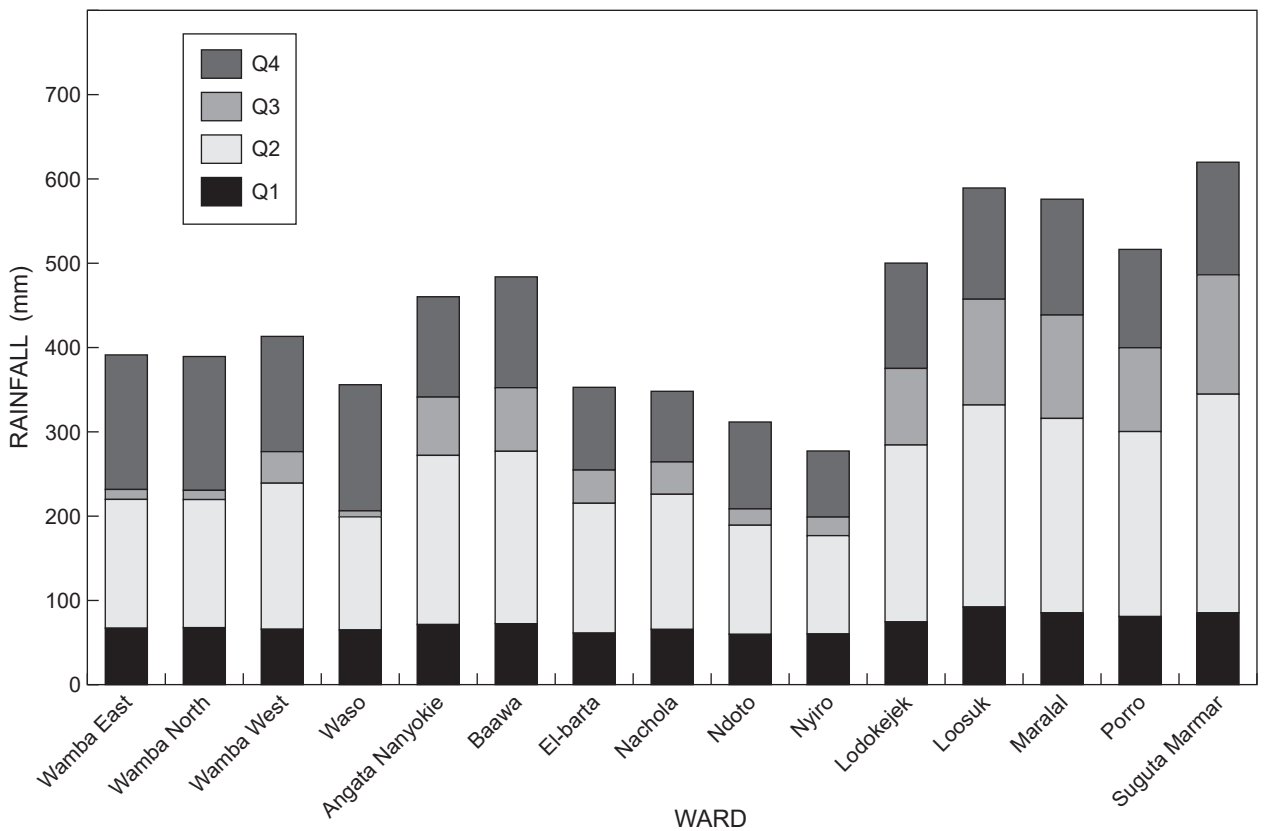

Figure 2: Seasonal rainfall in Samburu wards (2000–2018) from January–March (Q1), April–June (Q2), July–September (Q3) and October–December (Q4)

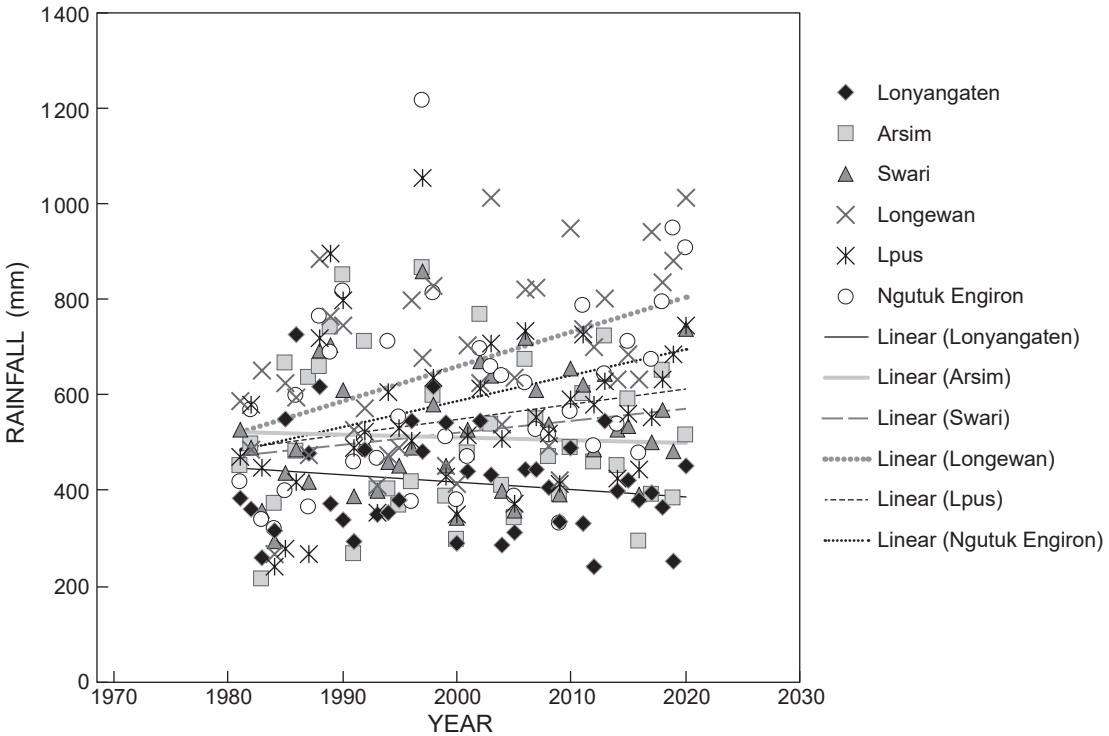

Figure 3: Annual trends of rainfall in the six study sub-locations (1981–2020)

Table 1: Analysis of determinants of herd mobility at household level

Factor	Important		Unimportant	
Water availability (*n* = 347)	336	(97.4%)	11	(2.6%)
Physical barriers (*n* = 345)	185	(53.6%)	160	(46.4%)
Type of livestock kept (*n* = 345)	273	(79.1%)	72	(20.9%)
Household labour (*n* = 345)	143	(41.4%)	202	(58.6%)
Pasture availability (*n* = 345)	345	(100%)	0	
Emergency of livestock diseases (*n* = 345)	251	(72.8%)	94	(27.2%)
External interventions (*n* = 345)	136	(39.4%)	209	(60.6%)
Conflicts (*n* = 345)	286	(82.9%)	59	(27.1%)
Availability of salt licks (*n* = 345)	274	(79.4%)	71	(20.6%)

Spatial distribution of herds in relation to rainfall patterns

During January to March, the herds in Samburu North are concentrated within Nachola and Marti areas, while others move towards Samburu Central and East. The livestock in Samburu Central and East moved to Laikipia and Isiolo counties (Figure 5).

It is usually wet from April to June, with the Samburu wards receiving between 116 and 260 mm of rain during this quarter except in cases where the rains are delayed or have failed. During these months, most of the pastoralists return their animals and graze them around homesteads; therefore the distribution of herds is widespread over the study areas. The exception for this are people with large herds of animals who prefer to remain either in Laikipia or at the Isiolo–Samburu border. Also, due to the degraded nature of rangelands in Samburu East (especially Wamba East and Wamba North), most of the livestock herds in this sub-county could still be found distributed within Waso ward (Figure 5).

The period July to September is usually considered the harshest, especially among the pastoralists in Samburu East. No rains occur in these areas during these months. However, some areas of Samburu Central usually receive rains between July and August. Therefore, livestock herds in Samburu East and North concentrated around Samburu Central, patches of Laikipia and along the Isiolo/Samburu border (Figure 5).

Heavy rains of between 130 and 160 mm are experienced in the lowlands of Samburu East between October and December. Therefore, vegetation growth and pasture availability is enhanced in these areas. During these months, livestock grazed within the homesteads and herd distribution is mainly around the study locations. However, some herds are still distributed in the areas around Kom in Isiolo county because pastoralists living in the degraded areas of the

Figure 4: Spatial distribution of livestock herds during different seasons of the year

lowlands move their animals to these areas where pasture and browsing is available (Figure 5).

Spatial distribution of herds in relation to NDVI

January to March are usually dry in most parts of Samburu with NDVI values of between 0.24 in the pastoralists grazing areas indicating low vegetation cover in these areas and 0.52 within areas covered by forests, therefore livestock herds were mainly concentrated in Samburu Central (Suguta Marmar and Baawa), Laikipia ranches (Kirimun and Sosian) and dry season grazing areas along the Samburu/Isiolo border (Figure 6). However, due to the security situation brought about by inter-communal cattle rustling around Baragoi, the herds from Nachola and Lonyangaten areas have always been restricted to their tribal boundaries despite the harsh climate (NDVI values of 0.24 and 0.31). Livestock from Arsim, however, is commonly distributed around Ndoto mountains during these months due to the favourable vegetation cover in these areas (NDVI values of 0.31 to 0.40).

In most of Samburu county, the period April to June experiences an increase in vegetation (NDVI value of up to 0.6); the degraded areas of the lowlands are the exception. During these months, most of the herds had left Laikipia areas and were distributed around homesteads in Lonyangaten, Swari, Longewan, Arsim, Lpus and Ngutuk Engiron (Figure 6). This period experiences higher NDVI values in almost all

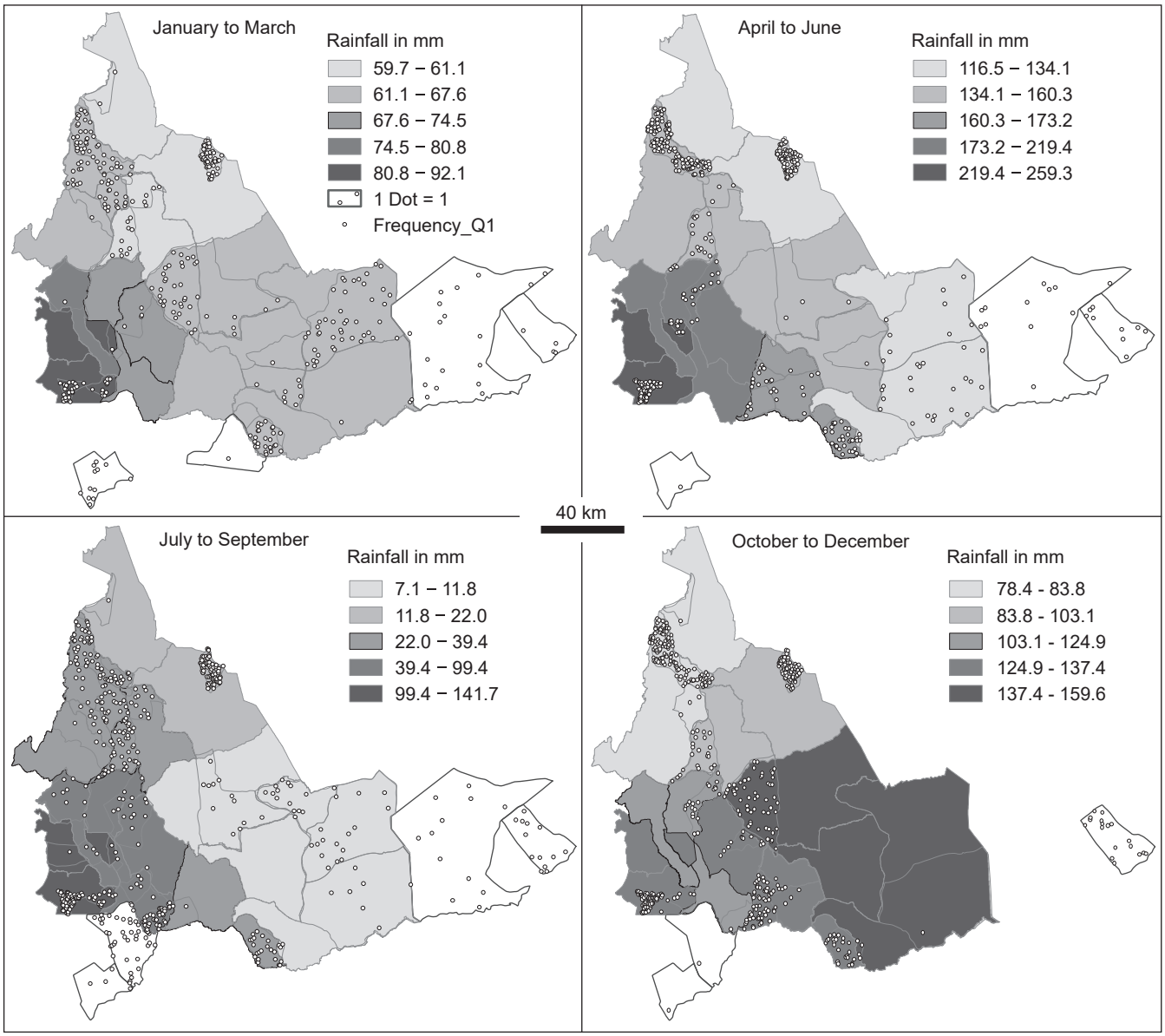

Figure 5: Spatial distribution of livestock herds in relation to rainfall amount

wards of Samburu Central (0.5–0.6) and Wamba North and East wards of Samburu East (0.37–0.50). In Samburu North, high NDVI values were noted in Ndoto Ward (0.37–0.50) and improved NDVI values in Nachola Ward (0.33–0.37). These values represent an increase in vegetation cover and the reason for the observed herd mobility patterns.

From July to September the NDVI values are reduced all over the county, but most significantly in the lowland areas (0.23–0.26). This is because the lowland areas experience a dry spell during this period, making pastoralists move their animals to the dry season grazing areas. Livestock from Samburu Central and Wamba West ward were distributed in Laikipia (around Kirimon, Sosian and Mount Kenya) while those in Wamba North, Nachola and Elbarta Wards were distributed around Marti dry season grazing areas. Those in Wamba East and Waso wards were distributed around the Samburu/Isiolo border dry season grazing areas (Kom and Losesia) and Serolipi areas (Figure 6).

The improvement of vegetation conditions in both the highlands and the lowlands of Samburu from October to December (0.30–0.60) means that increased pasture is available. Most of the pastoralists, especially in the lowlands, move their herds back home and graze them within the surroundings of their homesteads. As seen in Figure 6, most of the herds were no longer in areas around Laikipia and Losesia and were distributed around the study locations. The few that remained away were in Kom area.

Spatial distribution of herds in relation to temperature variability

A spatial analysis of seasonal temperature variability in Samburu County indicated that there were no differences

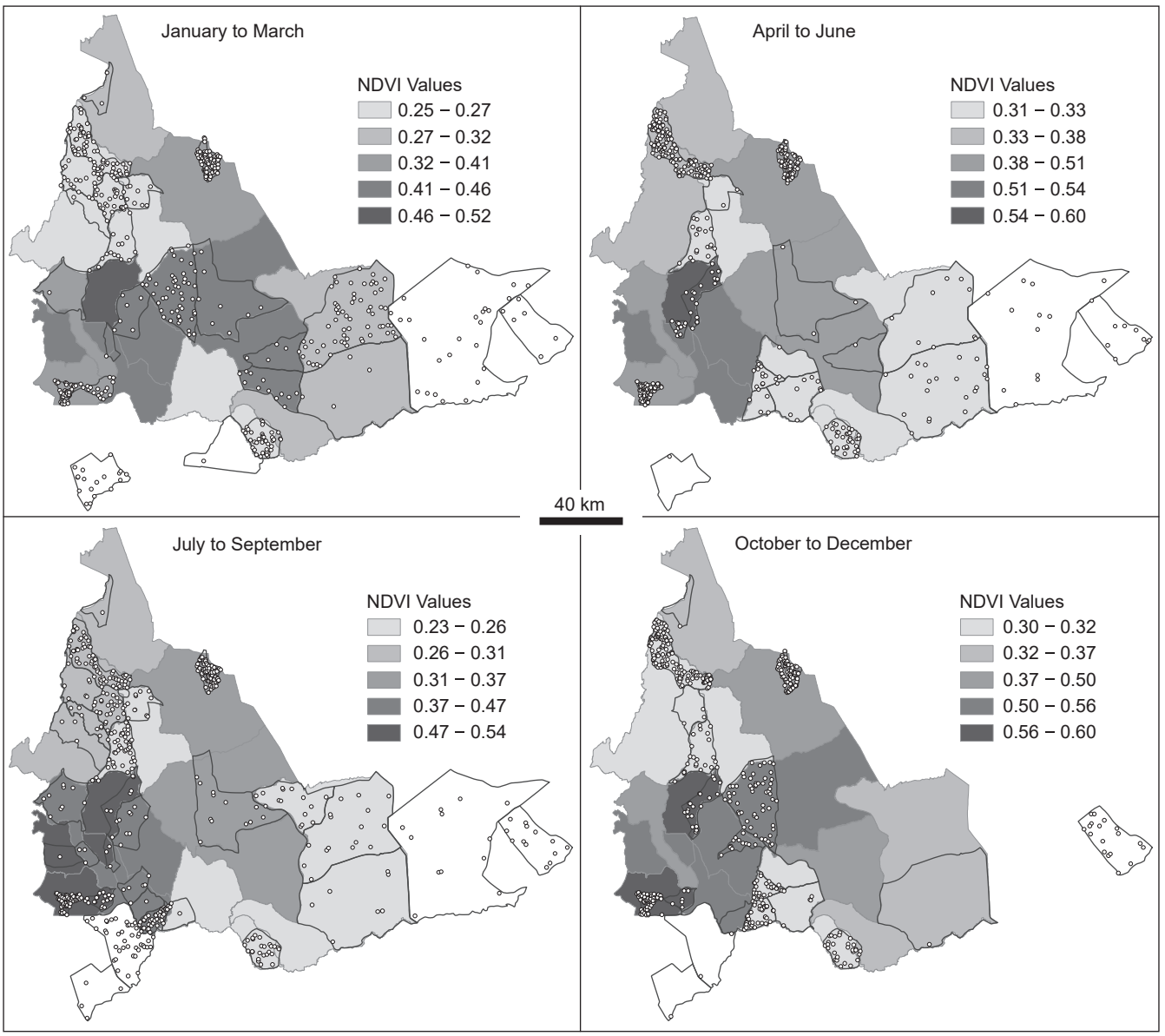

Figure 6: Spatial distribution of livestock herds in relation to normalised difference vegetation index (NDVI)

in spatial variability of this variable between January and December (Figure 7). The only differences were observed from January to March and July to September. During the January–March season, a general increase in temperature was recorded in Poro, Suguta Marmar and Lodokejek wards compared to the April–June and October–December seasons. During the July–September season, there was a general decline in temperature in Nyiro, Nachola and El-Barta. Specifically, no general change in herd distribution was noted with the change in temperatures between the different wards.

Discussion

The analysis of climate data from both USGS and the Kenya Meteorological Department shows the occurrence of four seasons in Samburu with the April–August period receiving more rains in the highlands than in the lowlands and the October–December season receiving more rains in the lowlands than the highlands. The January–March season receives depressed rainfall throughout the county. In Samburu, the long dry season in the lowlands lasts from June to September and part of October, while the short dry season lasts from late December to March. This affects the seasonal mobility of herds from the lowlands to the highlands and vice versa. Such mobility is more pronounced during July–September, a season which receives low amounts, prompting pastoralists to move their livestock to the highlands. Overall, the rains in Samburu are inconsistent, highly localised, unreliable and unpredictable from year to year and from location to location (Pas-Schrijver 2019; Samburu County Government 2018). In addition, the rains frequently come in the form of

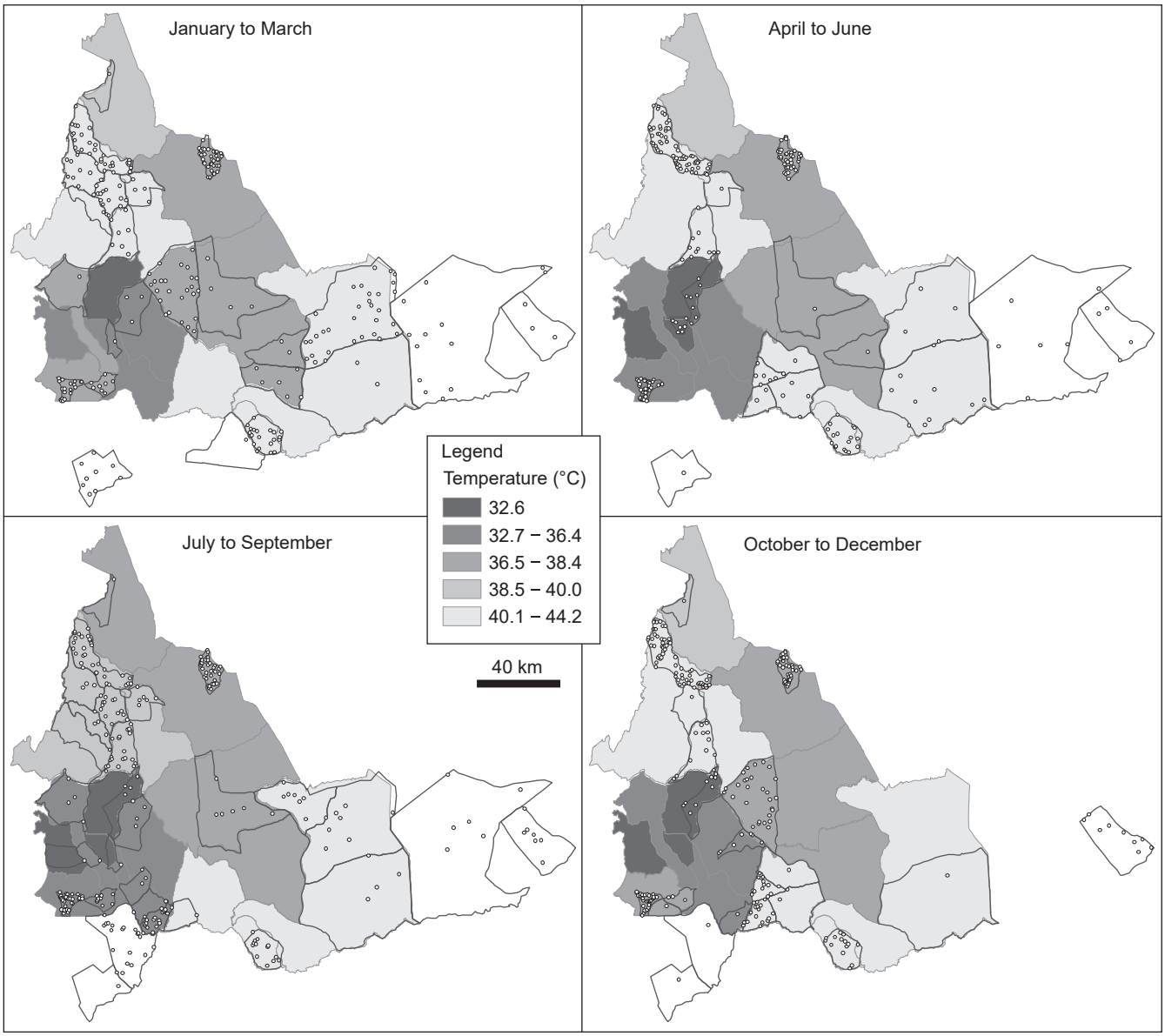

Figure 7: Spatial distribution of livestock herds in relation to temperature variability

brief, heavy storms. The soils absorb very little water, and the temporary rivers dry up within a few hours of rainfall (Samburu County Government 2018). This study also indicates a declining trend in rainfall amounts received in Samburu North and an increasing trend in rainfall amounts received in Samburu East and Central. The observation that the rainfall trend has been declining in Samburu North is in line with the United Nations Development Programme's (UNDP) climate change profile for Kenya which notes that heavy rainfall events have been increasing with no statistically significant trend (McSweeny et al. 2010). Generally, Samburu has a complex rainfall pattern. This is primarily due to the extreme variability and unpredictability of rainfall throughout the year, but also because the Samburu region includes both highlands and lowlands. The Lorroki highlands and the lowlands have significantly diverse rainfall patterns (Pas-Schrijver 2019).

Regular mobility of livestock is a key management strategy in Samburu's transhumant pastoral systems, with movements between wet and dry season grazing areas denoted by clear routes. As indicated in this study, the migration routes are north–south and south–north in the county, with movements mainly occurring in the drier months (January–March and July–September) and the wetter months (April–June and October–December). When grass is insufficient for the livestock, the herders take them either to the hills (Kirisia Forest, Matthews Range and Ndoto Hills), other parts of Samburu, and even locations like Kom in Isiolo, Marti in Baragoi, and some parts of Laikipia county. Pastoralists from the lowlands relocate to the Lorroki Plateau, Matthews Range

or even Samburu National Reserve (Pas-Schrijver 2019; Lengoiboni 2011). As a result, the most important response of pastoralists to rainfall fluctuations in terms of geography and time is migration (Adriansen 2008). During prolonged droughts, when pasture in the dry season grazing reserves are exhausted, Samburu communities resort to using fall-back grazing areas that are unusable during "normal" dry seasons due to remoteness, land ownership restrictions, animal sickness issues and resource use disputes. Such areas include Kom in Isiolo, Marti and Suyan in Samburu North and Sosian, and Marula in Laikipia. However, significant fragmentation of communal grazing areas under group ranches to individual ownership and changes in land use have severely impeded pastoral mobility in recent years, particularly in Samburu Central (Lesorogol 2008). Over the last five years, Kenya's National Land Commission has embarked on the process of sub-dividing land to individuals especially in Samburu Central (personal observation). Therefore, the grazing lands currently available for the pastoralists are the ones that are not yet sub-divided and the Kirisia Forest Reserve. Such areas include Kisima, Kirimon, Ledero and Lbukoi.

For this study, NDVI was used as a measure of pasture and browse availability. The values indicate different status of the land surface. Globally, very low values (0.1 and below) correspond to barren areas of rock, sand or snow (Sonneveld et al. 2008). In Samburu moderate values represent shrub and grassland (0.2 to 0.3), while high values (0.5 to 0.6) indicate areas with dense vegetation, including Kirisia Forest, Ndoto Mountains and the Matthews Range. Therefore, it was expected that herds would be concentrated in areas with higher NDVI values (0.3 and above). The NDVI values affected the distribution of livestock herds during the different seasons of the year. It is only in Samburu Central, which is endowed with good rainfall, that the pastoralists graze their animals around their homes all year round. This can be attributed to the good climatic conditions within Samburu Central with good rainfall patterns (500 to 800 mm annually). Rarely do livestock in Samburu East graze around homesteads due to low rainfall received and degraded pastures. The herds' spatial distribution patterns followed pasture availability, as shown by vegetation NDVI patterns. Areas with higher NDVIs of over 0.3 attracted herd concentration but with high *in situ* mobility to maximise on grazing of the most nutritious pastures. However, temperature variability did not seem to affect spatial distribution of herds as was the case in rainfall and NDVI values.

The pastoralists mentioned pasture availability as a key factor when considering where and when to move their livestock. Watering points, vulnerability to resource-based conflicts, species of livestock kept and presence or absence of diseases followed in that order. In another study by Lelenguyah et al. (2021) in Samburu county, Kenya, where 22 key informants were interviewed, similar observations on the determinants of herd mobility were made. While pasture availability is essential for the survival of livestock in an area, its scarcity also becomes a factor of insecurity and resource-based conflicts (Abroulaye et al. 2015). This is because conflict zones are often suitable grazing areas during dry seasons due to their non-utilisation during the rainy seasons, and private ranches in Laikipia are also illegally invaded in order to exploit the grass available (Mulianga 2009). Factors influencing decision making on resource utilisation by the pastoralists are many but attempts to rank them have been futile (McCabe 2010). This study focused on nine of these factors. While the list was not exhaustive, the factors are not independent of each other. For example, even though pasture was ranked as a key factor that determines herd mobility, livestock also need water and salt licks, which cannot be accessed if an area is prone to cattle rustling or infected by livestock diseases. But generally, decisions related to mobility involve a complex process of environmental, political and social factors. Pastoral decision-making and resource utilisation are complex and incorporate information that goes beyond the size or reliability of a given resource, including contextual factors such as disease, resource-based conflicts, water and pasture availability (Miller et al. 2014). According to Nori and Scoones (2019), the resource management and livelihood strategies used by pastoralists can inform decision making in a variable and uncertain environment.

Samburu and Turkana communities in Samburu North have their own livestock grazing areas. This is mainly because of the security situation brought about by inter-communal cattle rustling and resource use conflicts in the area. Due to many factors such as an increase in animal numbers, prevalence of insecurity, provision of water sources, expansion of other agricultural systems mainly in Central Samburu, and general resource deterioration, these tribal groups of North Samburu seek grazing resources outside their recognised tribal territory (Lesorogol 2008). The major problem for these groups has been the recurrent droughts in the area. The deterioration of pasture areas has made pastoralists stay longer in the more promising areas of southern Samburu, thus competing with other groups and creating new resource-based conflicts. These strategies have been used by pastoralists for centuries and have been discussed in detail in the literature over the last few decades (Galaty and Johnson 1990; Scoones 1995; Niamir-Fuller 1999).

Conclusions and recommendations

Wet season grazing areas and dry season grazing areas characterise the Samburu pastoral system. Because of the irregular rainfall pattern, animals move around the area in search of pasture and water, and grazing patterns are always shifting. One of the solutions to sound range management in this pastoral system is grazing management embedded in observed herd mobility and grazing resource use patterns. This can be achieved by establishing and implementing grazing programmes that can be reinforced within recognised community management structures such as councils of elders, grazing committees, group ranch committees and water resource management committees. Both the county and national governments must recognise and promote the critical role of pastoral institutions in facilitating pastoral adaptation and sustainably managing rangeland resources. As highlighted by Kratli and Toulmin (2020) and Mwamidi et al. (2023), it is important to strengthen customary institutions which play significant roles, including the control of access to resources and management of relations between different communities. Such institutions can be strengthened most effectively by developing policies that encourage customary

governance and provide pastoralists with a sense of security over their land. Dry land grazing areas, if well managed, can have multiple benefits of enhancing ecosystem services and improvement of livelihood adaption to climate change impacts.

A spatial relationship was observed between distribution of livestock herds and rainfall patterns. In most of the dry seasons, pastoralists end up in private lands in Laikipia and Samburu Central or in the government gazetted Kirisia Forest and the Samburu National Reserve where they have no formal access. As a result, violent clashes are expected between Samburu herders and private land owners or reserve officials. Developing formal grazing agreements between the community and the forest and reserve managements would help relieve the conflicts that arise during severe drought periods.

Declining trends in rainfall have been observed in Samburu North over the last 40 years. If this trend continues, it will have a large impact on pastoral livelihoods and will make pastoralism an unsustainable venture. Diversification of livelihood sources will help pastoralists cushion themselves against the effects of climate variability. In Samburu North, introduction of honey production through modern bee hives provided by the county governments and other partners is one such livelihood diversification strategy. Also, fodder conservation will go a long way towards supplementing natural pasture grazing. Several pastoralists in Samburu have begun to experiment with pasture cultivation, harvesting and making hay, and this will supplement the pasture available in the dry season grazing areas. Investments in veterinary extension, livelihood diversification and social safety nets can reduce pastoralists' vulnerability to extreme weather events.

Data availability — The data sets generated and/or analysed during this study and used in the production of this article are available from the corresponding author and can be availed upon reasonable request.

Conflict of interest — The authors declare that they have no conflict of interest.

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