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Responding to mobility constraints: Recent shifts in resource use practices and herding strategies in the Borana pastoral system, southern Ethiopia

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ABSTRACT

This paper investigates how Borana pastoralists of southern Ethiopia have adapted resource use and livestock mobility practices amid multiple constraints including rising population, loss of rangeland to other pastoral communities and changing access rights, among others. This study uses an innovative multi-scalar methodology to understand how herders' grazing management decisions are made within a context of communal regulations governing access to resources. Grazing itinaries specifying the grazing units used during the past year were established for 91 cattle herds and daily mobility was recorded through 12 months of GPS data monitoring of three herds in three zones within the Borana rangelands. The results revealed communal reorganisation of the grazing areas into units with designated periods of access. Despite the reorganization, herd mobility is severely limited, but to different degrees. In the zones facing most constraints, herd mobility is restricted to the grazing areas within proximity of the respective herder's settlement. However in all the areas, movement outside the herd owners' zone of residence is only practiced as escape mobility, '*baqa*' (to flee); instead of the formerly common '*godanna*' (to move). These constraints impede fundamental herd mobility needed to meet livestock nutrient requirements, which then affects resilience of the pastoral system.

1. Introduction

The Borana pastoral system was once considered to be an exemplary sustainable cattle production system in the East African drylands. This distinction has been dampened by diverse constraints limiting the amount of rangeland available for a growing population such as loss of grazing lands to other pastoralist groups (Kefale, 2010; Helland, 2006) and increased demand of land for other uses (Desta and Coppock, 2004; Tache, 2013) which pose challenges for livestock mobility.

Livestock mobility is recognised as an important production strategy to harness the high spatial and temporal variability of fodder resources in the rangelands. Successful pastoral production hinges on the selection of grazing areas that have above average quality and quantity of forage. This is how the animals may have the best available energy and nutrient intake possible throughout the year (Ellis and Swift, 1988; African Union, 2010; Krätli et al. 2013). Moving animals strategically to appropriate forage areas is the paramount management tool in pastoral systems to keep them ecologically and economically viable (Adriansen, 2006; Behnke et al. 1993; Niamir-Fuller and Turner, 1999). Furthermore, mobility can mitigate vulnerabilities to hazards such as droughts, ethnic conflicts and diseases (Bassett, 1986).

However in the last decades, pastoral production systems faced several challenges that curtailed herd mobility (Fernandez-Gimenez and Le Febre, 2006; Reid et al. 2014), which have become a threat to the system's economic and environmental sustainability (IUCN, 2012). The extent of these effects differs among pastoral communities. In Borana pastoral system of southern Ethiopia, grazing land is not only lost through competing uses and acquisition by other ethnic groups, but it is also degraded by bush encroachment. This bush encroachment in the formerly open plains arose following the ban of fire for rangeland management (Angassa Oba 2008). Additionally, state and other donor supported development initiatives have resulted in the disruption of

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longstanding community resource management systems (Homann et al. 2008).

As these multiple pressures build and subsequently limit livestock mobility, there is insufficient understanding regarding how herders adjust their grazing management to the more restrictive conditions. Both temporal and multi-scalar spatial analysis is needed to reveal herders' grazing management decisions within a context that includes communal regulations governing access to grazing land.

This paper provides a detailed analysis of contemporary Borana pastoralists' livestock mobility practices and shows how Borana have adapted their grazing management to different mobility constraints within three different zones in the Borana rangeland. This study also specifically makes a methodological contribution by using a multi-scalar approach that allows for zooming in from the community to the individual level and linking communal access regulations to individual mobility decisions. In this way, the analysis includes different scales and links them to each other. In order to allow for a comparative assessment, this study covers three Borana pastoral zones (*dheeda*) that include - *Dirre*, *Malbe* and *Golbo* - each with different characteristics such as population densities and availability of seasonal grazing areas.

Through application of mixed methods that included participatory mapping, grazing itinerary interviews and GPS tracking of cattle herds, this study provides detailed quantitative and qualitative data to understand herders' grazing management and the connection between herders' individual decisions regarding herd mobility and the communal regulations governing access to grazing land. To achieve this, we investigate the Borana pastoralists' access regulations in the different zones and document the shift in resource use and the herders' mobility practices both between and within three zones in the Borana rangeland.

In the next sections of the introduction, we present a brief review of methods used in studies of pastoral mobility and provide some background on the Borana pastoralists' resource access regulations and their resource use system.

1.1. Methods used in the study of pastoral mobility

The temporal nature and the spatial dimensions of pastoral mobility practices have often posed methodological challenges in obtaining information regarding its extent and herders' rangeland use strategies. In early livestock mobility studies, researchers obtained information on seasonal migration patterns of nomadic communities by following herd migrations and interviewing the herd owners (e.g. Stenning, 1957; Bassett, 1986). These studies were important for establishing the principles behind pastoral migration, but mostly described mobility by depicting the movement between seasonal grazing areas with arrows on coarse scale maps. They were limited in their discernment of timing and distance and patterns of livestock movements (Young et al. 2013), particularly at the level of daily mobility.

With multiple constraints building pressure in dryland livestock production systems, the need to understand the function of pastoral mobility at more refined scales led to adoption of GPS tracking devices. The initial GPS devices were expensive and limited in accuracy (Rutz and Hays, 2009). However in the recent past technological advancement has given rise to devices that are affordable and more accurate. In livestock studies, GPS tracking was used to learn about the grazing routes and related feed intake of pastoral animals. For instance, the studies of Turner et al. (2005), Turner and Hiernaux (2002) and Coppolillo (2000) revealed factors influencing livestock grazing distribution across agro-pastoral landscapes and implications for nutrient recycling. Moritz et al. (2010) and Butt (2010) used GPS tracking and observation of livestock grazing behaviour to provide details on grazing pressure and seasonal livestock movements in relation to biomass availability in different seasons. GPS tracking was also used for assessing herders' grazing management and their related knowledge and decision making. Sonneveld et al. (2009) delineated pastoralists' trekking routes using GPS while Adriansen and Nielsen (2002, 2005) and Young et al. (2013) combined GPS data with information from herder interviews to quantify mobility and characterize spatial-temporal mobility patterns.

This study focuses on understanding the herders grazing management and their mobility strategies. It is similar in approach to Adriansen and Nielsen (2002, 2005) and Young et al. (2013) but differs in the use of a multi-scalar method that provides an integrated understanding from the grazing area organisation at community level to individual herd mobility patterns. Also, it uses grazing calendar interviews on the last year grazing itinerary and geo-referenced "real time" grazing itineraries to analyse the differences in mobility patterns within and between three different zones of the Borana area experiencing different mobility constraints. Importantly, the study bases its analysis on landscape units identified by pastoralists in participatory resource mapping (Wario et al. 2015a) which enables understanding of the organisation and use of grazing resources relevant to herders' grazing management and decision making.

1.2. Pastoralists' regulation of access to grazing areas

Pastoral rangelands are managed under a communal tenure system with communal governance of the rangeland use. The daily management decisions are however done at the individual herd level. Pastoral communities do – to different degrees – regulate livestock movements across different grazing landscapes (Niamir, 1990). These regulations are either in response to resource variability or to manage resource deficits especially during dry periods. For instance, among pastoral communities such as the Maasai (Western, 1982), Turkana (Gulliver, 1975) and the Borana (Cossins and Upton, 1987) the rules that govern access to grazing resources are enshrined in the communities' codes of conduct and supported by their customary institutions. The access implied here is the right to gain benefit from communally managed resources (Ribot and Peluso, 2003) and in this case the rights to graze livestock in the various parts of the rangelands. The access rules adopted are created to match the seasonal resource variability of the respective pastoral systems.

Although such communal management has been widely credited as the best way of sustaining availability of grazing resources (Niamir, 1990), communal rules are often not recognized by state establishments resulting in *de facto* rights rather than *de jure* rights (Schlager and Ostrom, 1992). However, these *de facto* rights are expected to result in community self-regulation that limits the possibilities of negative effects such as over-exploitation of the resource base (ibid). Implementation of the rules relies on the commitment of those accessing land to the legitimacy of community self-imposed sanctions. The absence of these sanctions would likely result in little or no regulations as the cost of regulation by an outside entity such as the national government is prohibitive. Erosion of social controls and customary access of grazing resources consequently affect livestock mobility patterns (Homann, 2005; Oussouby, 1990). The effects are however expected to vary and depend on the context.

1.3. Borana pastoralists' resource use system

In this section, we give a short overview of the Borana resource use system, based on findings by Cossins and Upton (1987), Helland

(1982), Coppock (1994) Oba (1998) and Homann (2005). The Borana resource use system is based on zones defined by pastoralists' as *dheeda*. The *dheeda* are differentiated by Borana pastoralists based on their differences in altitude, rainfall and some other characteristics of the grazing resources. *Dheeda* encompass smaller resource management units called *madda*, which are further divided into smaller units called *reera* and *arda* (Coppock, 1994; Helland, 1982). The relationships between the various units are elaborated in Fig. 1. There are five *dheeda*, namely *Dirre*, *Gomoole*, *Wayaama*, *Malbe* and *Golbo* (Oba, 1998) in the Borana region of Ethiopia (Fig. 2).

Due to the differences in rainfall and other biophysical properties, grazing resources in the Borana rangelands have high spatial and temporal variations (Coppock, 1994; Cossins and Upton, 1988). The central parts of the rangelands (*Dirre dheeda*) are endowed with permanent traditional deep wells, *tula*, and perennial grasses. The peripheral areas to the east and west (*Wayaama*, *Malbe*, and *Golbo dheedas*) are characterised by limited water supplies. The northern part, *Gomoole*, is a sub-humid area that mainly acts as dry season grazing (Oba, 1998).

In the past, Borana pastoralists lived a semi-sedentary lifestyle with settlements mainly located in the central parts of the rangelands. Livestock have always been herded and access to different grazing areas was managed through the division of livestock into milk herds (*haawicha*) and dry stock (*foora*). While the *haawicha* herds grazed close to the settlements, the *foora* herds moved to peripheral areas of the territory accompanied only by herders, covering a radius of up to 40–45 km (Helland, 1982; Oba, 1998). When surface water sources were exhausted, *foora* herds retreated to settlement areas. This method of resource use shifted pressure between the different parts of the rangelands enabling the settled areas to replenish. It also provided access to areas associated with livestock performance enhancement properties (Homann, 2005; Oba, 1998).

However over the last decades, a number of changes occurred in the Borana rangelands that have adversely affected the resource management system. A major interference was from the Land Reform Proclamation Act of 1975, which divided the rangelands into Pastoral Associations (PA) for administrative purposes. Although the divisions mainly followed borders of the traditional *madda* (Kamara et al. 2004), the main challenge was that the rights to grazing resources were redefined by PA membership and mobility to cross was given only with permission from the PA administration (Helland, 2002).

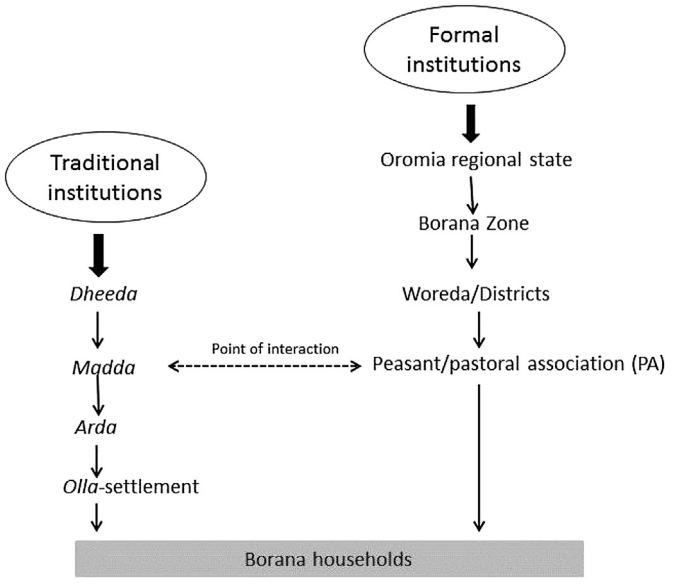


Fig. 1. Traditional and formal institutions in Borana (modified from Kamara et al. 2004).

These challenges have been compounded by population growth, resulting in settlement expansion into formerly peripheral areas, particularly following the development of permanent water sources (Homann et al. 2008). The loss of significant grazing areas to other ethnic groups (Helland, 2002; Kefale, 2010) further decreased rangeland availability in this Borana pastoral system. Additionally, bush encroachment has adversely affected grass availability in most of the rangelands (Angassa and Oba, 2008; Coppock, 1994; Cossins and Upton, 1987; Dalle et al. 2006). On the other hand, the frequent occurrences of extreme climatic conditions such as droughts and a general decrease in precipitation (Viste et al. 2013) provide additional resource use challenges.

2. Methods

2.1. Study area

We conducted field research among the Borana pastoralists of southern Ethiopia from December 2012–February 2014. The Borana rangelands cover approximately 95,000 km^2 (Coppock, 1994). The area is predominantly arid and semiarid and rainfall is bimodal. Based on this bimodal rainfall, the Borana pastoralists divide their year into four seasons: the long rainy season (*ganna*) that occurs between April–June, the cold dry season (*adoolesa*) which runs from July–September, the short rainy season (*hagaya*) which occurs from October–November and the hot dry season (*Bona hagaya*) from December–March (Coppock, 1994; Cossins and Upton, 1987; Helland, 1982).

2.2. Data collection

Data was collected from three Borana pastoral zones (*dheeda*) of *Dirre*, *Malbe* and *Golbo* (Fig. 2). From each *dheeda*, two neighbouring *madda* were selected. We adopted a methodological approach with steps for analysis at different scales that allows for consideration of the meso-scale communal grazing area organization in relation to micro-scale level of individual herd daily mobility. The method consists of a) participatory rangeland use analysis, b) grazing itinerary interviews and c) tracking of actual grazing itineraries using GPS. For the participatory rangeland use analysis, we selected 8–10 knowledgeable elders and experienced herders from each site with the support of village headmen (*abba olla*). Using satellite images of the *madda*, the participants indicated the location and extent of all grazing units, villages and water sources resulting in a community developed grazing area map. The aim was to understand how the use of the rangelands - already identified into grazing units (Wario et al. 2015a) - was organized and how the access is regulated by the community.

Data was also obtained from 91 herd owners using grazing itinerary interviews to learn about the variety of individual herd movement patterns in each area. Stratified and random sampling methods were used to select these herd owners. During the selection of participants, stratification was achieved by using administrative levels where each *madda* or PA is divided into three sub-units called *reera*, *each* comprising a number of villages. We obtained household lists from the PA offices and sorted them into different cattle herding units with the support of PA representatives and community elders. The names of the herding units owners were separated into the respective *reera* and 5 were randomly selected from each, making a total of 15 from each *madda*. Through

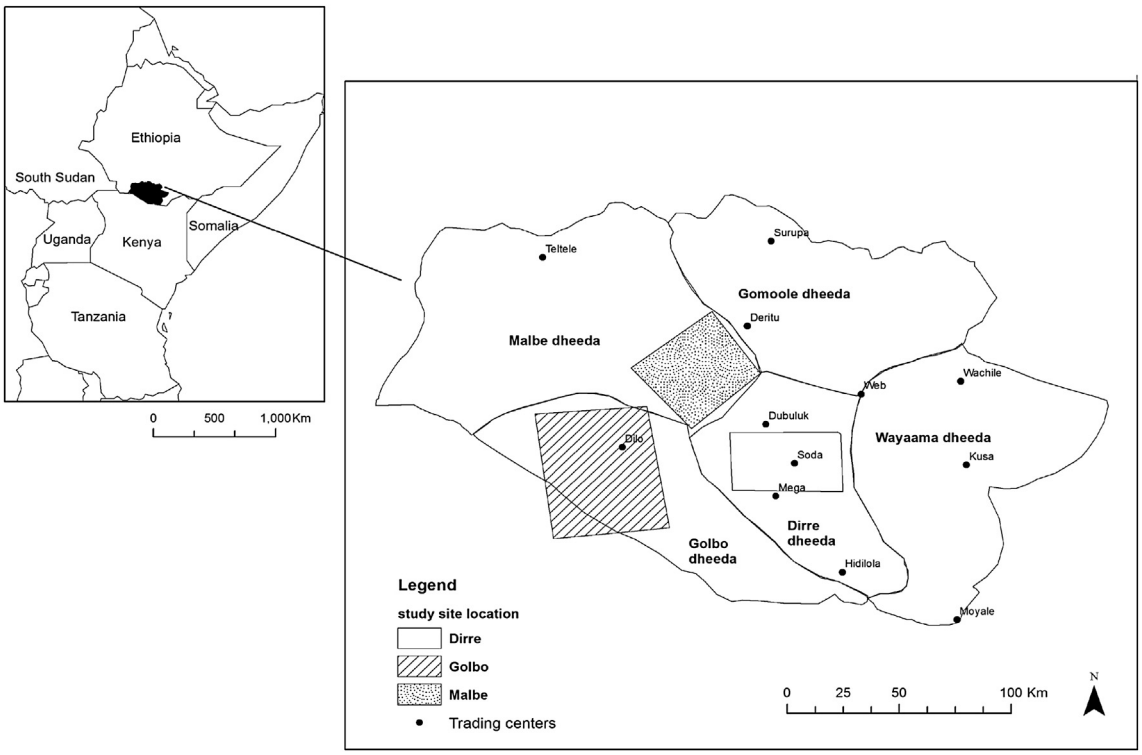


Fig. 2. Map of the region of southern Ethiopia showing the location of the zones (dheeda) and the study sites.

discussion with the community elders, representative herding unit sizes were 20–100 heads of cattle.

In these grazing itinerary interviews, the herd owners systematically narrated where their herd grazed over the last 16 months (five seasons), using the grazing area maps to indicate the location according to the Borana traditional calendar. The grazing itinerary recorded during the interviews covered 480 months cumulatively (30 herds × 16 months) for each study site. Information obtained includes: names of grazing units accessed by the herd, the reason for selecting the grazing unit, and duration of stay. Information on whether the herd was accompanied by the household or moved as *foora* and the reasons for leaving the grazing unit were also documented. In the case that a herd was split during the time of the interview, the itinerary of the main herd section was documented.

To further understand grazing strategies and movement patterns at the individual herd level, actual grazing itineraries of cattle herds were recorded using GPS devices carried by herders. Trackstick II GPS devices (by Telespial Systems Inc.) were selected due to ease of portability and use of dry cells that could easily be replaced by participating herders. Initially, we began by tracking nine cattle herds (three from each of the study sites). However, we report on only three cattle herds (one from each of the three study sites) where we consistently obtained tracks for a period of 12–14 months. The herders carried the GPS devices by fastening them onto their belts throughout the herding day. The herders were left with batteries for replacements and monthly visits were conducted to download the data and also to interview the herders regarding their grazing itineraries. The methods and resulting data are summarised in Table 1.

2.3. Data analysis

The herders' information on the grazing area use categories was digitized and geo-referenced in ArcGIS 10.2. The proportions of grazing areas in each use category were computed from this digitized area map. Settlement density was calculated by dividing the total area mapped per site by the number of villages recorded in each site. This provides an indication of the grazing areas available to herders in each village and demonstrates relative differences in rising demands for the use of limited space.

From 91 participatory grazing itinerary interviews the types of mobility strategies practiced by herders were identified. The average number of months each herd spent in each respective grazing area was computed in SPSS version 20.

The herd itinerary data, logged using GPS, was analysed using Touratech-QV5 software to obtain the daily grazing patterns of each herd. This was then used to compute the mean daily grazing distances for each herd. By displaying both geo-referenced routes they trekked along with days spent at water points identified on the grazing area map, grazing itineraries could then be separated into watering days and grazing only days. The mean daily grazing distance for watering days and grazing days were calculated and the differences were tested using independent sample *t* tests. To identify seasonal spatial differences in grazing patterns, the GPS data was separated into dry season and wet season and converted into point density maps in ArcGIS 10.2. The pattern was overlaid onto the grazing area map for comparative purposes. These point density images were interpreted by triangulating herders' monthly interviews to explain the reasons behind the patterns.

3. Results

The results are organized into two main sections. In the first section, we present the communal organisation of the grazing areas which provides the context for individual grazing management in each study site (zone). The second part compares herd mobility patterns identified from herders in the light of varied levels of constraints in each zone.

Table 1
Summary of the methods and data collected.

Method	Objective	Data collected
Rangeland use analysis that involves focus group discussion with 8–10 elders and experienced herders	To assess grazing area organization and regulation of access	Location of villages, their grazing area types and how access is regulated
Grazing itinerary interviews with 91 cattle herders covering 16 months period	To understand the shift in resource use strategies and mobility patterns and communal and individual herd level	Number of changes between grazing units, length of stay and reasons
GPS Tracking of grazing itineraries of three herds and monthly herder interviews		Actual herd movement itineraries for 12–14 months

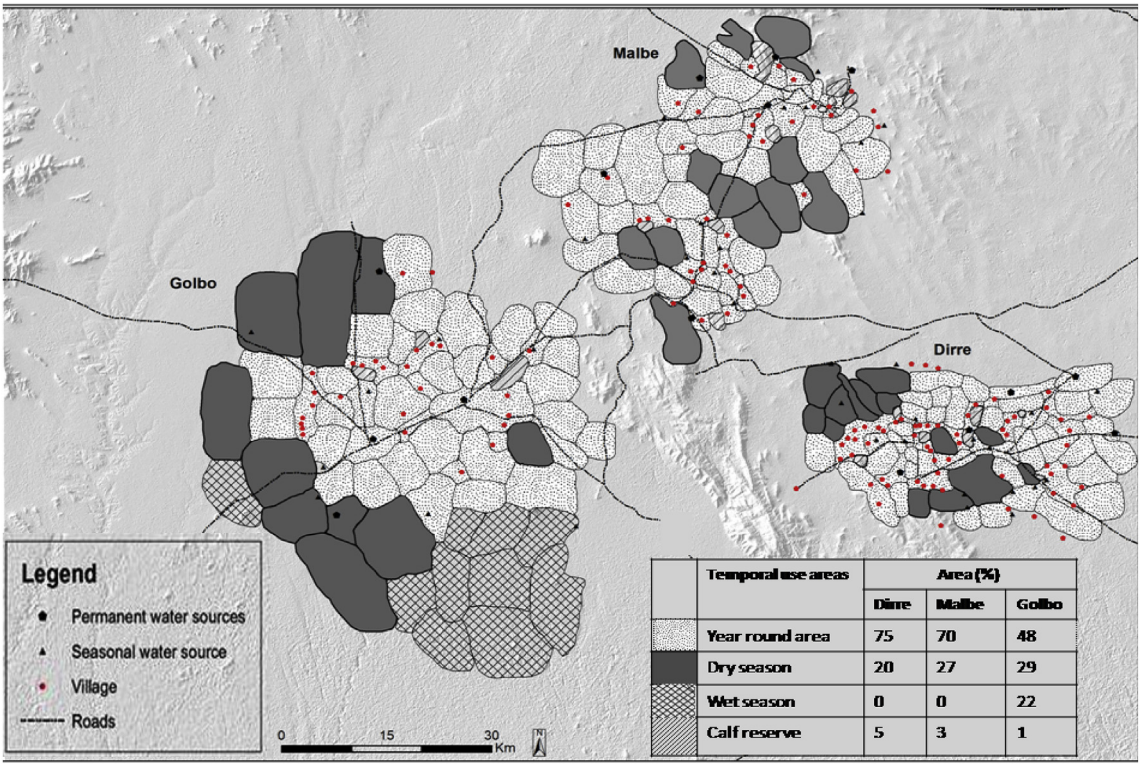
3.1. Access regulations to grazing areas in the Borana rangelands

The average available grazing area per village in the study areas of *Dirre*, *Malbe* and *Golbo* was estimated as 15.4, 37.2 and 94.2 km^2 respectively. The communities divided these grazing areas into categories each with corresponding designated times of access (henceforth referred to as 'temporal use areas'). A total of four temporal use areas were identified in the study sites: year round use, wet season use, dry season use and calf reserves. According to these classifications, over 70% of grazing areas in *Dirre* and *Malbe*, and 50% in *Golbo* were under year round use (Fig. 3). Less than a third of the total areas in each study site were dry season areas, while the presence of wet season grazing areas was only reported in *Golbo*. Areas used as calf reserves covered between 1 and 6% of the land surface in the study sites (Fig. 3).

This resource use system relies on rainfall amounts and distribution. For instance, the herders noted that while the system worked well over the past two years (2012–2013), that this was not the case in 2011 due to lack of rainfall. The temporal use areas are not fenced, hence each member of the community has the mandate to guard and report breaches. Herders who breach regulations are fined 500 Ethiopian Birr per incidence. This sanction was endorsed by the customary institution, the *gada*, and has been in practice for the past 5 years.

Rangeland use analysis with the herders further revealed that the herders only had permanent customary right of access to the temporal use areas within daily grazing reach from their settlements. Access regulations to areas beyond the daily grazing reach differed between the sites. Traditionally access to areas not within the daily grazing reach was possible through the use of *foora*, where the household remained sedentary while the herd moved with the herders. However, the practice of *foora* within the precinct of *Dirre* and *Malbe* was not allowed by the communities. According to the herders, the ban on the use of *foora* was to reduce competition for limited dry season fodder supplies. The herders from these areas were only allowed to use *foora* when rainfall in their area was not favourable. In such cases, they could join other existing settlements but could not establish camps anywhere they preferred. Contrary to these examples, we found that the use of *foora* to access the wet season area and most of the dry season areas is still allowed in *Golbo*.

In *Malbe*, in response to the restriction on the use of *foora*, herders devised a unique grazing area use strategy. They classified the year round use areas into two: i) foothills which are areas close



Temporal use areas	Area (%)		
	Dirre	Malbe	Golbo
Year round area	75	70	48
Dry season	20	27	29
Wet season	0	0	22
Calf reserve	5	3	1

Fig. 3. Map of the study sites showing the location and proportions of the different temporal use grazing areas in the respective study sites.

to mountain ranges to the north and south of the *madda* and ii) *Diida* which are low lying areas to the west. Access to these areas is accorded through the establishment of two settlement types: main settlement (at the foothills) and subsidiary settlement (in *Diida*). Herders establish these extra settlements by dividing their families into separate household units. The herders reported that the practice was motivated by the need to explore variability in grazing resources given the restriction of *foora*. The areas in the foothills have better water supplies with slower desiccation rates allowing for some of the hills to act as dry season reserves. On the contrary, the *Diida* area has limited water supplies and desiccates relatively faster but is associated with enhancement of livestock reproductive performances during the wet season. Interviewed herders noted that this practice enabled them to access grazing in both areas by shifting their livestock between the two settlements.

3.2. Mobility types in different temporal use areas

3.2.1. Herd mobility patterns at the grazing unit level in the different zones

The analysis of the retrospective grazing itinerary of these 91 cattle herds revealed that herders practiced three main cattle mobility types, classified as daily, seasonal and escape mobilities. These mobility types differed in their purpose and geographical extent. Daily mobility is the everyday departure to the pasture and return to the settlement in the evening. This practice of returning to the settlement at the end of the grazing day restricts daily grazing distances. Daily mobility was mainly used to access year round use areas (Table 2), which were also in close proximity of settlements. Daily mobility is also entrenched in both seasonal and escape mobility, around pastoral camps. Seasonal mobility involves moving the herds (as *foora*) to wet season areas that are associated with productive performance enhancement and later retreat to dry season reserves to minimize weight loss. Escape mobility, on the other hand, involves moving herds to evade hazards. The direction and distance travelled depends on the geographical extent of the hazard to be avoided. The herders distinguished this type of mobility using the term *'baqa'* ('to flee') as opposed to '*godanna*' (to move) when referring to seasonal mobility.

The herders' mobility practices differed within and between zones as demonstrated by the varied amounts of time spent in each temporal use area. Although all of the 91 herds spent part of their grazing time in year round use areas, those from *Dirre* spent significantly longer in these areas while those from *Golbo* spent the shortest amount of time there (Table 2). However, the time spent by herds from the three study sites in the dry season areas were not significantly different; 80% of *Golbo* herds accessed dry season areas as compared to about 50% of those from *Dirre* and *Malbe*. Also in *Golbo*, 50% (n = 15) of the herds spent part of their grazing time in the wet season area for performance enhancement, while herds from *Dirre* and *Malbe* lacked such opportunities. The time spent by herds outside their own *madda* was not significantly different between the sites. However, about 60% of *Malbe* herds, compared to 19% and 33% of *Dirre* and *Golbo* herds respectively, spent time in other *madda* due to below average rainfall reported during part of the study period.

In addition to the differences in herd mobility between the different zones, and also within each zone, the individual herd mobility patterns and the time spent in different temporal areas varied. A cluster analysis of the individual herd itineraries showed that in *Dirre*, 13 herds spent their entire time in year round use areas, with two others following a similar itinerary except for a brief visit to the neighbouring *madda* (Fig. 4). 12 of the remaining herds divided their time between year round and dry season areas while four others spent part of their time in all of the available temporal use area options. The time spent by herds in the respective temporal areas depended on the proximity of their settlement to such areas. For example, the herds from settlements that were too far from dry season areas spent all their time in year round use areas because they were unable to reach the dry season areas on a daily basis.

In *Malbe*, four herds spent all of their time in the year round use area (with the exception of one herd that stayed in the foothills and 3 herds which partially accessed the *Diida* area). The other herds spent varied proportions of their grazing time in the different temporal grazing areas, but only 1 herd spent time in all of the temporal options available, as shown in (Fig. 4b).

In *Golbo* none of the herds spent all of their time in the year round use areas. Instead, the herds spent most their time in the dry season areas, which is due to the distance from the settlements which offer better grazing. Three other herds that spent most of their time in year round use also partly visited the wet season area. 11 other herds spent about 70% of their time in dry season area and the rest of their time in the year round use area. The remaining herds spent varied times in the different temporal use areas, with three of them accessing all of the available temporal areas (Fig. 4c).

The time differences in the duration of stay by herds in a given seasonal grazing area across the three sites exhibited a geographically varied pattern of resource use. This was influenced by the distance of the areas from the settlement associated with a respective herd. A continuum of reduced mobility is observed as areas available for grazing decreased from *Golbo* to *Dirre*. Differences in the geographical extent of mobility in the three study sites are demonstrated by examples of the most common mobility patterns. Such typical herd movements are displayed on the grazing area maps in Fig. 5a–c.

Fig. 5**A** shows mobility of Kutulo Huqa's herd in Dirre. The herd only used daily mobility from the settlement throughout the study period. It alternated its grazing time between the year round use area and dry season fodder reserves. The herd grazed in the year round areas for the periods Dec'11 to Jan'12, April–Aug'12, and mid-Nov'12 to mid-Jan'13 (**a,c,e**). The rest of the time (Feb–Mar'12, Sept - Mid Nov'12, and mid-Jan – Feb'13 (**b, d, f**)) the herd was in dry season area. In March'13 it moved into larger dry season area to the south.

Table 2
Types of mobility and average number of months spent by cattle herds in various temporal use areas over 16 months.

Temporal use area accessed	Mobility types	Average number of months cattle herds spent in temporal use areas (number of herds in parenthesis)		
		Dirre (n = 31)	Malbe (n = 30)	Golbo (n = 30)
Year round use	Daily mobility	11.5[a] (31)	8.1[b] (30)	5.9[c] (30)
Dry season use	Daily and seasonal mobility*	7.8[a] (16)	9.3[a] (16)	9.3[a] (24)
Wet season use	Seasonal mobility	0	0	2.9 (15)
Outside own *madda*	Escape mobility	4.5[a] (6)	4.6[a] (19)	3.7[a] (10)

[a]Identical superscripts indicate that the means are not significantly different at p = 0.05 between each site.
*Seasonal mobility to dry season areas mainly practiced in Golbo.

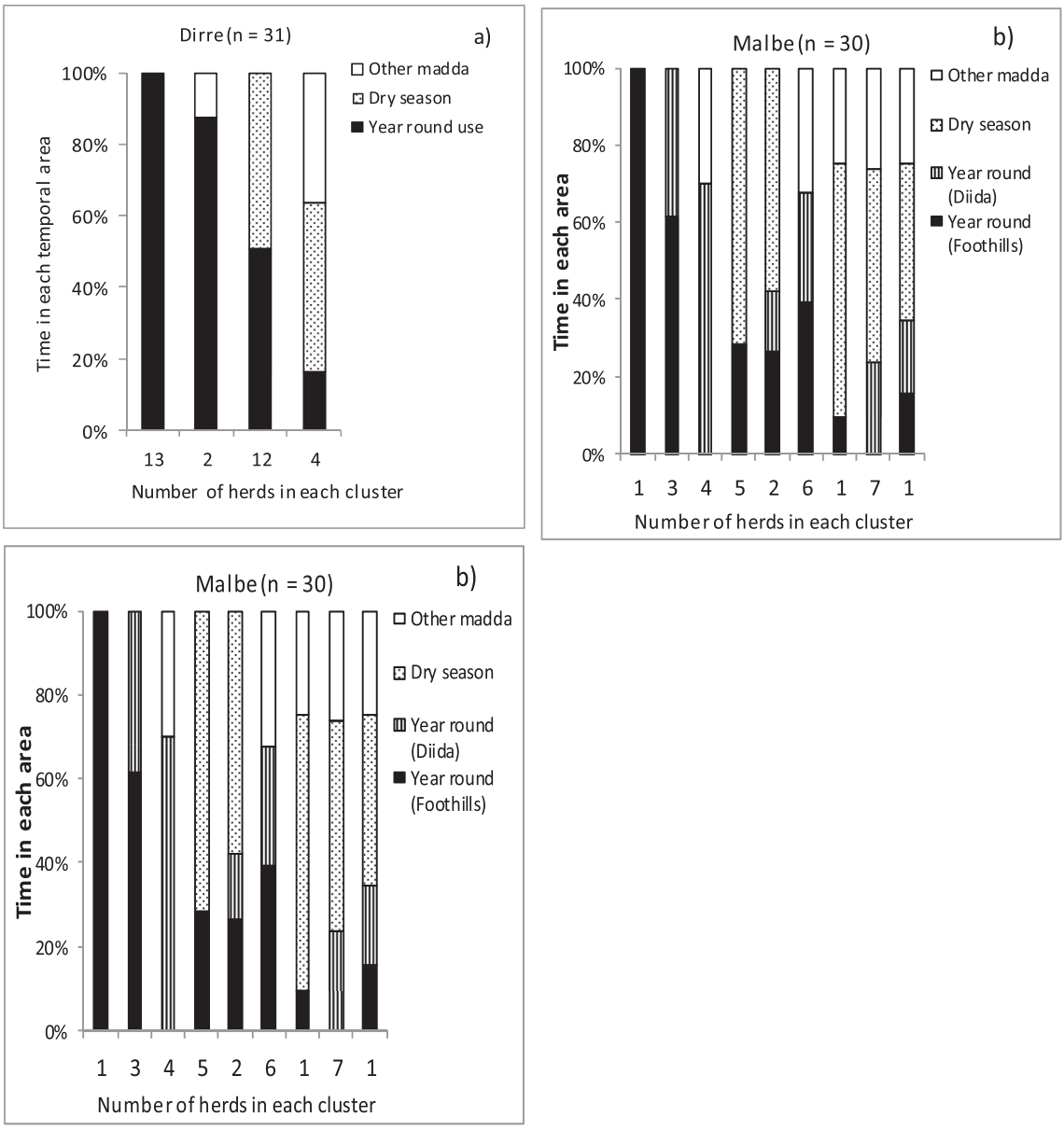


Fig. 4. Herds clustered by the percentage time spent in each of the temporal use areas in a) Dirre b) Malbe and c) *Golbo*.

Fig. 5**B** shows the movement of Godana Kale's herd in Malbe. The herd mainly used daily mobility and accessed both year round areas of foothills and *Diida* by establishing a subsidiary settlement. Between Dec '11 and Jan'12 the herd accessed the *Diida* area. From Feb'12–Mar'12 it moved to the grazing reserve on the mountains, in the extreme north of the map. When long rains began in April, the herd moved down to areas around its home base till mid-July'12. Later from mid-July through Nov'12 the herd accessed dry season area on a hill near its home base. In Dec'12–Feb'13 the herd again moved to the mountain grazing reserve. The herd retreated to area around the home base in Mar'13 as the mountain reserve was exhausted and long rains were yet to begin.

Fig 5**C** shows the mobility pattern of Denge Arbale's herd in Golbo. The herd combined daily and seasonal mobility. From Dec'11-mid Apr'12 the herd used seasonal mobility to access the dry season area in the north. When long rains began in April, the herd, again using seasonal mobility, moved south to the wet season area for 2.5 months. Later (July'12) the herd retreated and used daily mobility in areas around its settlement before again proceeding to the dry season areas in the north by mid-August. From mid-October the herd moved back to areas around its home base and returned to the dry season area from Mid-Dec'12 till March'13.

3.2.2. *Daily herd mobility patterns in the different zones*

With the retrospective grazing calendar, we detected the mobility between grazing units. To further analyse mobility patterns within the units, we tracked one herd from each zone. The three cattle herds covered a total grazing distance of 4197.4 km over 338 days of tracking, averaging 12.4 km per day (Table 3). In each of the study sites, the herders travelled longer average distances during watering days. The differences were significant in *Dirre* and *Malbe* at $p > 0.05$ (independent sample t-test).

The individual herd itineraries were separated into wet and dry seasons and displayed as point density maps. This showed that the cattle grazing activity was more intense in areas closer to the settlements particularly in the wet season (Figs. 6–8). Away from the

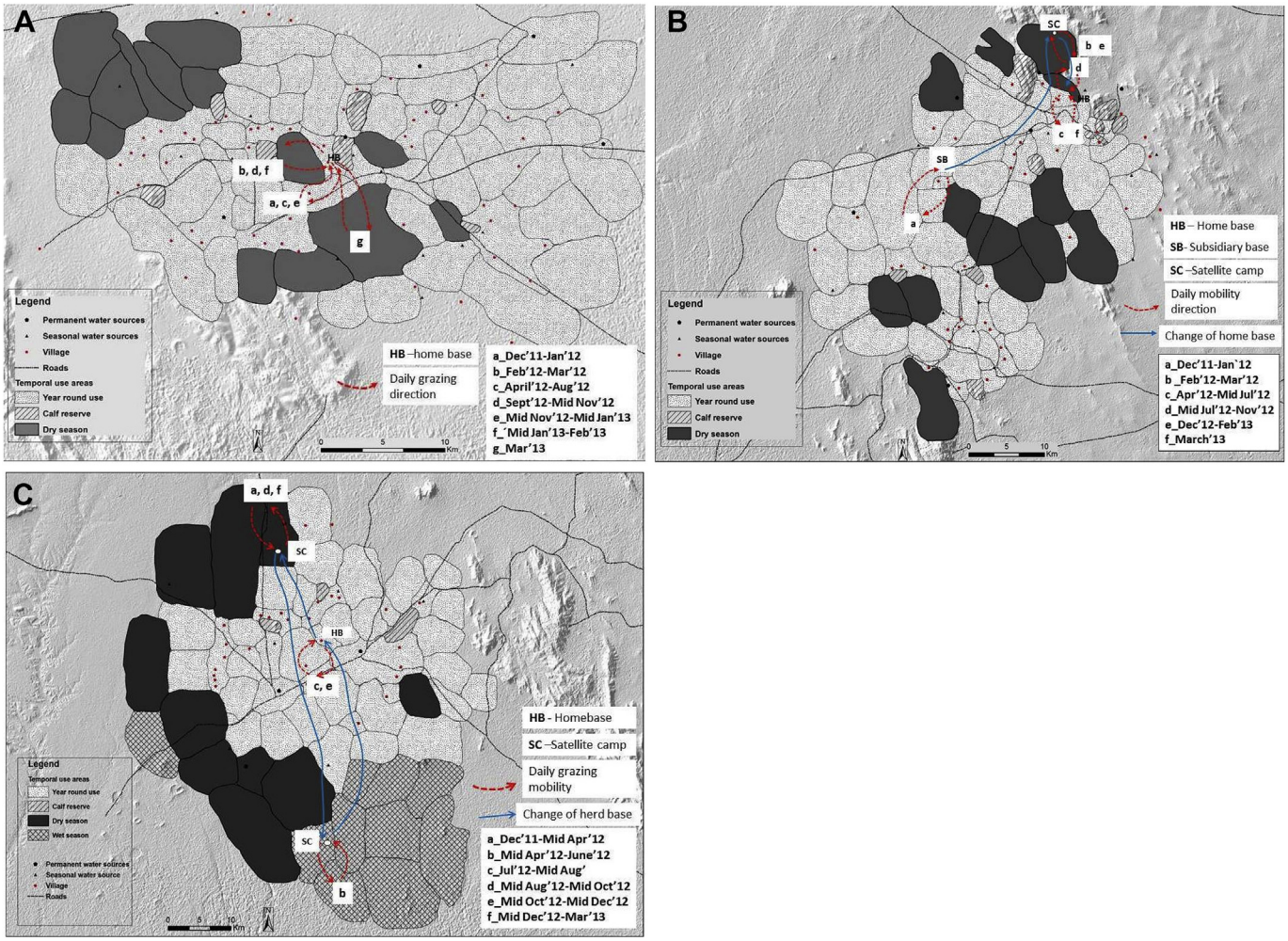


Fig. 5. Selected cattle herd grazing movements between December 2012–March 2013 in each of the respective study site A) Dirre, B) Malbe and C) *Golbo*.

settlement, the itineraries were skewed in different directions in each season as shown in Figs. 6–8 for each study site.

3.2.2.1. Herd grazing itineraries during wet seasons. Dirre's herd grazing distances in the beginning of the wet season (late March-Early April 2013) were less than 5 km in radius around the settlement. The grazing during this time was concentrated to the southwest of the herd's home base (Fig. 6a). The herder selected this area because it had no settlements and also because the access regulation for the dry season areas to the northeast had already been restricted. However, this grazing area lies towards the permanent water source of the Madhacho tula wells, which are traditionally not grazed during the wet season. During this period the herd exploited water pools along the grazing itinerary. Later in the season (from May 25th 2013), the itinerary changed, mainly on watering days, as the herd accessed water pans about 10 km (each way) from settlements (Fig. 6a). According to the herder, the choice of the distant water pan, instead of the closer wells, was due to community regulation prioritizing access to surface water before access to permanent sources.

The *Malbe* herd grazing itinerary was similar to that observed in *Dirre* where the herd mainly remained within the proximity of settlements. However, during part of March–April 2013, this herd left its *madda* due to delayed long rains (GPS data is lacking for this period). The herd returned, when the area received rainfall in May, and approximately grazed within a 6 km radius around the settlement. From mid June 2013, the herd accessed water from a pan about 10 km to the southeast (Fig. 7a) although another water pan closer to his settlement also had water. The herder indicated that his choice was influenced by the community decison to save the water pan closer to the settlement for a later period.

Table 3
Summary of the GPS herd tracking data.

Dheeda of herd origin	Dirre	Malbe	Golbo
Total number of days the herd was tracked	128	103	107
Total grazing distance the herd travelled over the tracked period (km)	1473.3	1214.5	1509.6
Average daily grazing distance on non-watering days (km)	9.2 ± 1.8	10.2 ± 2.2	13.4 ± 4.6
Average daily grazing distance travelled on watering days (km)	15.9 ± 2.7	15.5 ± 3.2	15.1 ± 4.7
t test (p = 0.05)	0.0001	0.0001	0.41

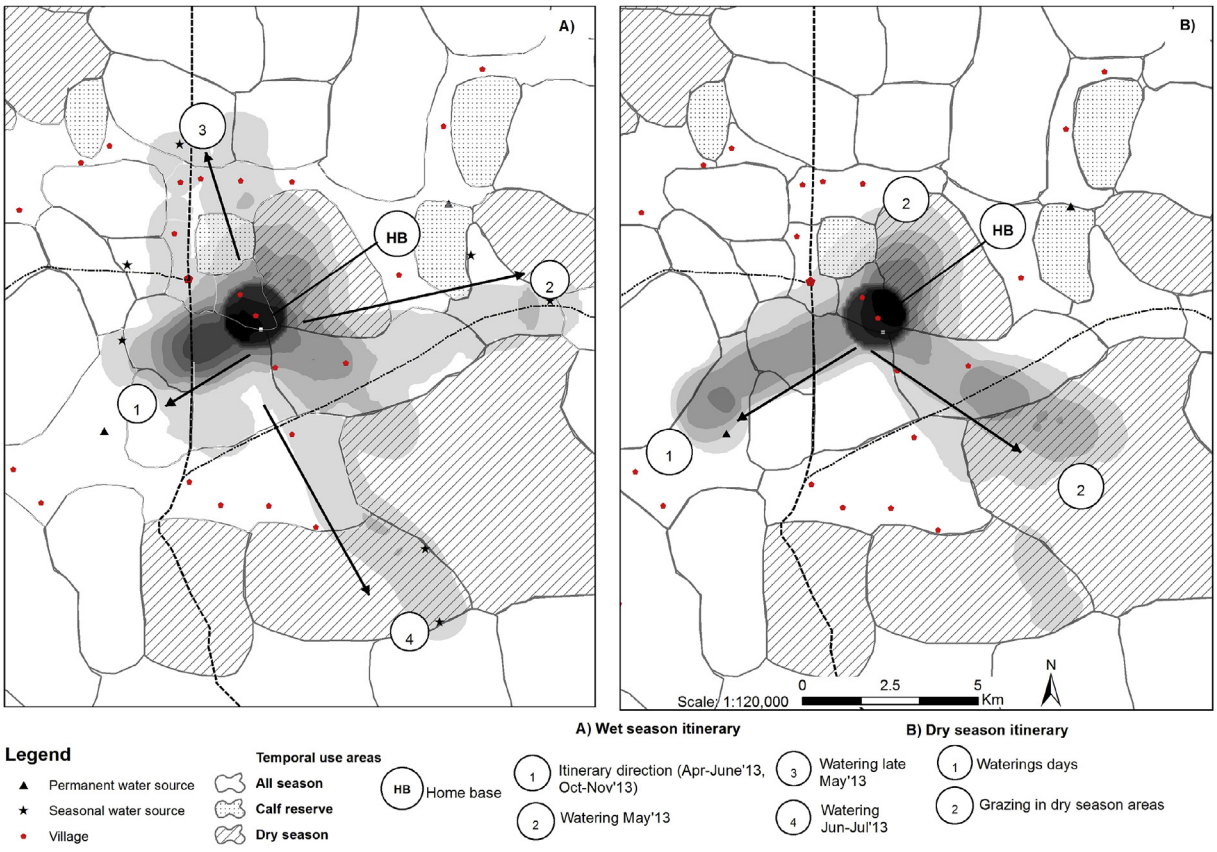


Fig. 6. GPS tracked grazing itinerary of a cattle herd from *Dirre* (Dec'12–Feb'14).

The *Golbo* herd spent the beginning of the wet season (late March-mid April 2013) in a dry season grazing reserve on a hill, south of the settlement (Fig. 8a). Part of April and May, the main herd moved as *foora* south to the wet season area, over 35 km away. During this time, the herd was only accompanied by the herders and not with the household. From mid-May, the herd moved back to the settlement area but proceeded about 15 km north of their original settlement and established a temporary home-base accompanied by the household. The reason for this change was better rainfall conditions such that water was again available in the water pans. Later in July, the animals were moved farther north with only the herders to the dry season area leaving behind a few cows with the household at the temporary home-base. The herd returned to the temporary home-base when the short rains (*hagaya*) began in late October 2013. During this period the daily itineraries were repeatedly towards same direction. For example from October 28th to November 27th, the herd grazed towards the northeast of the temporary home-base and later going north-west from November28th to December 6th. The herder explained that this followed forage availability that was influenced by rainfall distribution in the area. As of December 7th 2013, the herd returned to its original home base.

3.2.2.2. ii) Herd grazing itinerary during dry seasons. Dirre herds' dry season grazing movement was limited to dry season areas and the permanent water sources of the Madhacho wells (Fig. 6b). The herd at first accessed a small dry season area situated to the northeast of the herd's home-base but later changed to a larger reserve to the southeast (Fig. 6b). On watering days, the herd returned to the smaller dry season reserve because the larger reserve was out of reach. Later during the dry season, the watering frequency increased from every second to every third day. With this change, the herd could graze in the large reserve (with better forage) during the day after the watering day. The herd grazed in the smaller reserve next to the settlement on both the watering day and the second day after watering. This was a trade-off between going for better fodder located further away and staying in a poorer fodder area but with limited energy expenditure. The grazing itinerary for the herd from *Malbe* was similar during this period to that of the *Dirre* herd. The only difference was that the *Malbe* herd had a shorter access time to a dry season area due to limited rains.

In *Golbo*, the dry season grazing directions were mainly towards the location of dry season areas and permanent water sources. Note the difference in scale between the *Golbo* (Fig. 8) and the other two areas (Figs. 6 and 7). The community regulations regarding access to dry season grazing areas influenced the choices made by the herder. In Golbo, the herder was allowed to use *foora* to access the distant dry season area. The herd owner chose to access the distant larger grazing reserve during the initial part of the dry season following the community decision to save the smaller reserve next to the village for later time.

4. Discussion

4.1. Integrated methods in the study of pastoral mobility

The multi-scalar method adopted by this study allowed for analysis of mobility practices from the level of the organization of community grazing areas and associated access regulations to the level of individual herds and their daily grazing mobilities. At the community level, participatory rangeland use analysis provided insights into the grazing spaces available to herders. It revealed

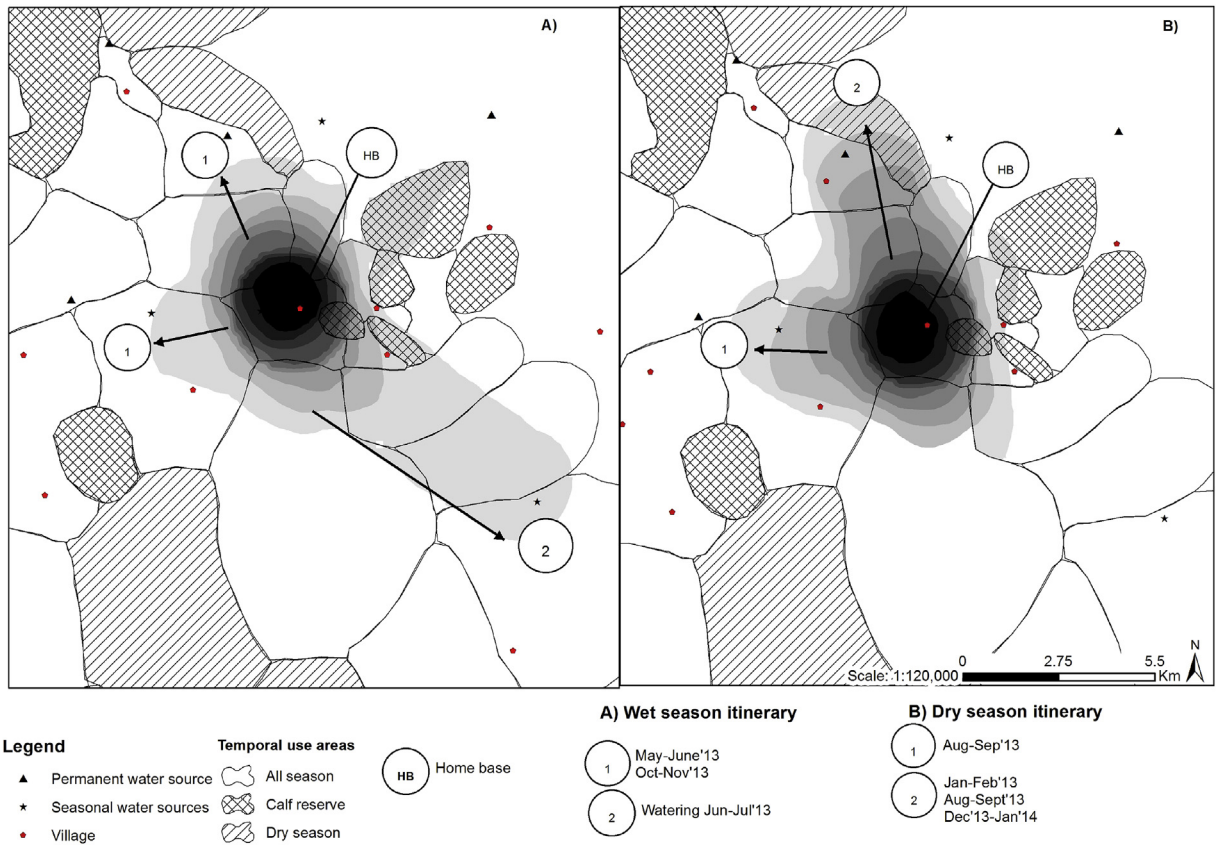


Fig. 7. GPS tracked grazing itinerary of a *Malbe* herd (Jan'12–Feb'14).

communities' attempts to reorganize their rangeland use in the presence of differing mobility constraints. The retrospective assessment of grazing itineraries enabled a detailed analysis of resource use patterns by a large number of herds across several seasons. The geographic pattern of these mobilities were elicited by making use of communal grazing area maps containing grazing units classified by the herders as the spatial basis for the temporal assessment of individual grazing itinaries. This also made possible a comparative analysis of the grazing practices across the three zones. The GPS data provided a finer scale analysis of daily grazing practices by quantifying the grazing distances and showing the daily movements of individual herds within the grazing units. Triangulation of the information between the methods was important to gauge consistency of the collected data at the different scales. This methodological approach therefore; enabled a fine scale analysis of mobility as recommended by Turner and Hiernaux (2002). Further, it helped to quantify mobility patterns as conducted by Adriansen and Nielsen (2002, 2005), and could show variability in grazing practices in a pastoral system Coppolillo (2000) both between and within the different pastoral zones.

4.2. Shift in Borana pastoralists' resource use regulations

The current system of resource management shows a shift from the earlier documented practices in the Borana pastoral system. Previously, areas with permanent water sources and perennial grasses such as *Dirre* were dry season areas, with grazing towards the water sources prohibited during the wet seasons (Helland, 1982). The areas of *Malbe* and *Golbo* which are characterized by ephemeral vegetation and limited water sources hosted fewer settlements and were mainly wet season use areas (Coppock, 1994; Cossins and Upton, 1987; Helland, 1982). This practice enabled the herders to utilize the variability in grazing resources provided by the differences in characteristics of these areas (Oba, 1998). Currently, herders categorized the same areas into different temporal uses as a coping mechanism because herders from each *madda*/PA now rely on the resources within their territory. This intensification of use within the *madda* is accompanied by less movement between *madda* within the *dheeda*, such that there has been a constriction of rangeland utilized by each herder in this Borana pastoral system.

The temporal use areas, with their differing sizes in the different *dheeda*, underscored the varying levels of spatial constraints faced by the herders across the Borana pastoral system. *Dirre*, with its higher population density and relatively smaller grazing areas available to the villages was the most constrained area, while *Golbo*, in this respect, was the least constrained. The absence of a wet season grazing zone in both *Dirre* and *Malbe* is a clear indication of reduced resource feed limitation. It also means that the herders from *Malbe* and *Dirre* lacked nutritious wet season pastures, which are important for quick recovery from weight loss that occurs during dry periods (Angassa and Oba, 2007). These limitations further reflected the higher percentage of grazing units that are under year round use, which encompass over 70% of the grazing areas in *Dirre* and *Malbe*. The large increase in the area under year round use from about 50% a decade ago (Kamara et al. 2004), is partly the repercussion of loss of grazing areas to other pastoral communities (Helland, 2006; Homann, 2005; Kefale, 2010). Additionally, increasing settlement densities resulting from population expansion puts more land under year round use. Although communities' decisions to re-organize grazing areas into temporal use zones might improve feed availability, it falls short of providing the flexibility in grazing unit use the herders utilized decades ago.

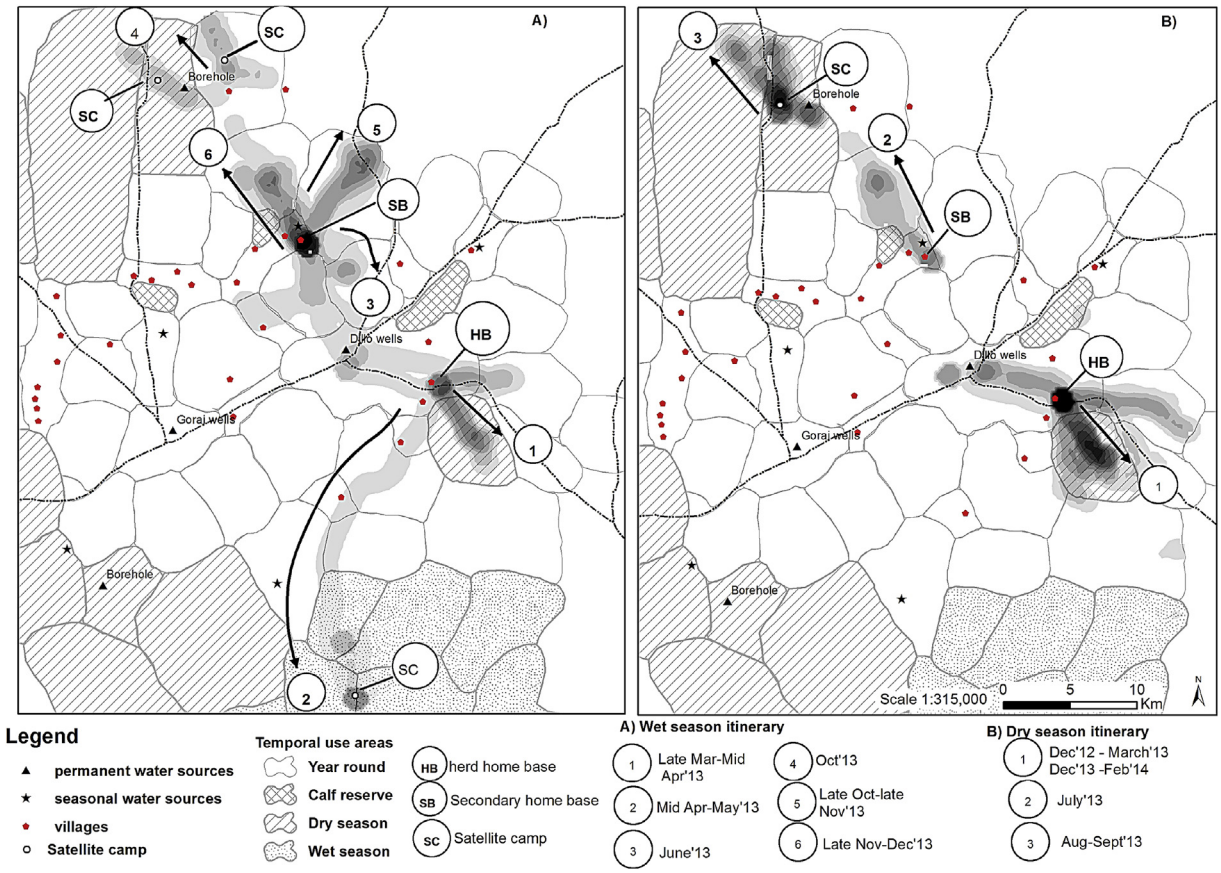


Fig. 8. GPS tracked grazing itinerary of a Golbo herd (Dec'12–Feb'14).

With this shift, another major change in resource use is the restriction on the practice of *foora*. In *Dirre* and *Malbe*, the communities disallowed the use of *foora* to reduce competition as grazing areas dwindled. *Foora* is currently only allowed in cases of drought; and even then the herders cannot set up *foora* camps wherever they intend to, but must move into existing settlements. While the previous Borana resource use system allowed open rights of access to any pastures by the residents of the Borana territory (Cossins and Upton, 1987; Helland, 1982), this shift limits the *de facto* rights of the residents to their *madda*. These restrictions concerning the practice of *foora* and the temporal use categorization affect the herders' choices for daily and seasonal mobility.

4.3. Adapting mobility patterns to reduced grazing spaces

The mobility pattern and the amount of time spent within settlement proximity, differed with each site. *Dirre* herders' mobility patterns were characterised by the absence of seasonal mobility and herds spent relatively longer time in the year round use areas due to high settlement density. In *Malbe*, the practice of having different home-bases in separate settlements of the *madda* provided more choices and was reflected in the higher variety of mobility patterns observed. In *Golbo*, on the other hand, the herders spent less time in the year round use areas and apart from staying in the dry season area they also had access to wet season grazing areas.

A significant change in mobility patterns was the limited use of seasonal mobility that was previously used to boost reproductive performances of the livestock by taking advantage of variability in nutrient fluxes. Seasonal mobility was documented only among the *Golbo* herders while in *Malbe* the dual settlement practices accorded minimal change between areas with different resources. This denotes another significant change from previous practices where seasonal mobility allowed herders to target areas that offered a quick accumulation of fat reserves in rainy seasons (such as *Golbo*) and to retreat to dry season areas (e.g. *Dirre*) that slow down weight loss (Oba, 1998; Homann, 2005). Contrary to this Borana example, in the pastoral system in parts of the Sahel (e.g. Turner et al., 2014), herders from densely populated areas showed more mobility, especially during the wet season, as they moved outside their areas to access resources elsewhere. As mobility is the principal strategy for livestock production in arid and semi-arid rangelands (Breman and de Wit, 1983; Krätli and Schareika, 2010), such restrictions are expected to erode the environmental and economic resilience of pastoral systems (Leslie and McCabe, 2013; Krätli et al. 2013).

Despite the constraints, herders from the three zones provided different reasons for internal variations in the amount of time spent by herds in temporal use areas. In *Dirre*, for instance, the differences observed in mobility patterns were due to the location of the settlements in relation to dry season areas and restrictions on the use of *foora*. In *Malbe*, the households that could not afford two home bases were more restricted and therefore spent more time in the year round use areas. In *Golbo*, only half of the herds visited the wet season area, and instead spent most of their time in dry season areas. The *Golbo* herders who did not visit the wet season areas were mostly those from the western side of the *madda*. These herders have settlements in close proximity to the dry season areas where they spent about 70% of their time. On the other hand, those situated towards the east had limited proximity to the dry season areas and hence the majority of them chose to visit the wet season

area. Therefore, the herders with better proximity to the dry season areas seem to have forfeited the short term stay in wet season areas for longer durations in dry season areas with relatively stable fodder availability. This showed how the herders' operational contexts influenced their mobility decisions. Such reshaping of resource access was also observed by Homann (2005) in other parts of the Borana pastoral system following water development that led to settlement spread to former wet season areas. Also, studies (e.g. Adriansen and Nielsen, 2002; Oussouby, 1990) among the Sahel pastoralists reported changes in herding practices from the long distance movements to micro-nomadism within designated pastoral units resulting from the development of permanent water sources.

Generally, livestock mobility patterns have been predominantly limited by dwindling grazing spaces in Borana rangelands. Mobility being an integral management aspect of livestock production in arid and semi-arid environments, a high degree of variability and flexibility in mobility practices is a pre-requisite for productive pastoral systems (Baker and Hoffman, 2006; Dyson-Hudson and Dyson-Hudson, 1980; Leslie and McCabe, 2013). Currently three aspects in the Borana pastoral production context – settlement density, concentration of livestock around settlements and increased year round use areas – are likely to contribute to reduced feed availability and resource degradation. It has been shown that the cattle reared in the *Dirre* zone of the Borana rangelands with lowest mobility have significantly lower reproductive performances and reduced lifetime performance (Wario et al. 2015b).

5. Conclusion

This paper provides a detailed analysis of the contemporary Borana pastoralists' livestock mobility practices and how they have adapted grazing management strategies in a context of increasing constraints. This study also specifically makes a methodological contribution by using a multi-scalar methodological approach that allows for zooming in from the community to the individual level. Our results reveal that a pastoral system reeling under diverse pressures has difficult choices to make as limited spaces constrict access to grazing resources. These constraints erode the management efficiency of the resource use previously associated with this pastoral system. Seasonal mobility is severely impeded by the quasi abandonment of between *dheeda* mobility and the ban of *foora* practices in large parts of the Borana area. The Borana pastoralists try to cope with these mobility constraints through the reorganization of grazing area access. However, the scope of these regulations to manage the availability of livestock feed and to protect environmental integrity remain limited. From the results we also infer that the degree of constraints affecting pastoral mobility varied between and within the different parts of the Borana pastoral system, which point to the need for management initiatives that are context specific. On the other hand, the reduced ability to make use of ephemeral resource availability will eventually lead to reduced herd productivity. Our research shows that the constraints affecting herders' principal productive and adaptive strategies threaten the system's resilience. This analysis can be used as basis for rangeland use planning with Borana pastoralists and with representatives of their customary institutions in order to seek possibilities for transformation of the system to strengthen livelihood security among pastoral households.

Conflict of interest and submission declaration

The authors declare that this is their original work and has not been published previously and it is not under consideration for publication anywhere else. The authors also declare that they do not have any perceived or actual conflict of interest.

Statement of informed consent

In this research there were no animal subjects directly involved and consent was always obtained from the community members interviewed during data collection.

Authors' contributions

Hussein Wario, collected the data, carried out the data analysis and drafted the manuscript. Hassan Roba provided substantial comments on the manuscript, Brigitte Kaufmann, guided data collection and provided substantial comments on the manuscript. All the authors approved the content of the manuscript for submission.

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