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3 authors:

Hussein T Wario
Universität Kassel

Hassan Roba
National Museums of Kenya

Brigitte Kaufmann
Deutsches Institut für Tropische und Subtropische Landwirtschaft

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Shaping the Herders' "Mental Maps": Participatory Mapping with Pastoralists' to Understand Their Grazing Area Differentiation and Characterization

Hussein T. Wario[1] · Hassan G. Roba[2] · Brigitte Kaufmann[1]

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Abstract Understanding the perception of environmental resources by the users is an important element in planning its sustainable use and management. Pastoralist communities manage their vast grazing territories and exploit resource variability through strategic mobility. However, the knowledge on which pastoralists' resource management is based and their perception of the grazing areas has received limited attention. To improve this understanding and to document this knowledge in a way that can be communicated with 'outsiders', we adopted a participatory mapping approach using satellite imagery to explore how Borana pastoralists of southern Ethiopia differentiated and characterized their grazing areas. The Borana herders conceptualized their grazing areas as set of distinctive grazing units each having specific names and characteristics. The precise location and the borders of each grazing unit were identified on the satellite image. In naming of the grazing units, the main differentiating criteria were landforms, vegetation types, prevalence of wildlife species, and manmade features. Based on the dominant soil type, the grazing units were aggregated into seasonal grazing areas that were described using factors such as soil drainage properties, extent of woody cover, main grass species, and prevalence of ectoparasites. Pastoralists ranking of the seasonal grazing areas according to their suitability for cattle grazing matched with vegetation assessment results on the abundance of desirable fodder varieties. Approaching grazing area differentiation from the pastoralists' perspectives improves the understanding of rangeland characteristics that pastoralists considered important in their grazing management and visualization of their mental representation in digital maps eases communication of this knowledge.

Keywords Southern Ethiopia · Borana · Grazing units · Seasonal grazing areas · Pastoralists' rangeland classification

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✉ Hussein T. Wario
husstwario@yahoo.co.uk

[1] German Institute for Tropical and Sub-tropical Agriculture (DITSL), University of Kassel, Kassel, Germany

[2] National Museums of Kenya, Nairobi, Kenya

Introduction

The recognition of pastoral production systems as a socio-ecological system that are under the stewardship of human users (e.g., Janssen et al. 2007) emphasizes the need to appreciate the role of human actors, who through their management practices have shaped and maintained their production systems over many years (Kaufmann 2007; Ostrom 2009). Previously, rangelands used by the pastoralists were often represented as ecological systems, and hence ecological characteristics were used to describe and classify them and also to propose management strategies (e.g., Lusigi 1984; Schwartz et al. 1991). However, this does not give due consideration to the fact that pastoral communities perceive and appraise their environments as a resource for production and that the users view is influenced by the production purpose. Bathelt and Glückler (2005) described this as 'relational' view of resources, which means that something can only be distinguished as a resource *in relation* to a particular use and user(s). Hence, in pastoral production environments, the way users perceive and classify their resources in relation to grazing use forms an important basis in its utilization and management.

Recent literature points to the fact that the pastoral producers view the characteristic variability of grazing resources as an asset for livestock production (see Kratli et al. 2013; Krätli and Schareika 2010), which they manage through strategic practice of mobility (AfricanUnion 2010; Ellis and Swift 1988; Niamir-Fuller 1999). The practice and management of strategic mobility relies on the herders' spatial knowledge and their perception of resource distribution and its seasonal variations (Fernandez-Gimenez 2000). This spatial knowledge, through which the herders know where to find fodder at the respective times of the year, is a result of human's possession of mental representation of their spatial environments that includes detailed characteristics of places at a variety of scales and connections between them (Tuan 1975; Istomin and Dwyer 2009).

The existence of representation of the spatial environments in the minds of humans and animals was first postulated by psychologist Edward Tolmin (1948). Tolmin invented the term 'cognitive map' to describe a map like a representation that guided animals within their environment. By the 1960s, the concept gained wide recognition and use in geography adopting the synonym 'mental maps' (Schenk 2013; Tuan 1975). However, there was also objection to the existence of such mental maps, particularly by the proponents of an alternative theory; the 'practical mastery', which postulates that humans do not have map-like representations in their minds, but memorize spaces as visual perspectives encoded in a particular order and have knowledge of routes that connect them (e.g., Ingold 2000). However, there is consensus that mental representations do exist and that they act complementarily with practical mastery in guiding human understanding of their territory (Gell 1985; Istomin and Dwyer 2009). Moreover, such mental representations are accredited with high levels of accuracy particularly when produced as consensual maps that combine intergenerational knowledge of a community as opposed to individual perceptions (McKenna et al. 2008).

With this recognition, it was apparent that making the mental maps explicit was a significant step towards understanding resource users' perception of their resources. Attempts to transform mental maps into cartographic forms began as sketch maps, but this posed challenges as it varied between individuals depending on factors such as perspectives and scale (Imani and Tabaeian 2012). Further development of mental maps into cartographic form was influenced by the need of researchers and development staffs to get a better understanding of spatial contexts of indigenous community environments that were not available in standard cartographic forms. This led to the development of participatory mapping approaches to transform the mental maps of communities into conventional forms used in participatory decision making (Herlihy and Knapp 2003). In the past decades, participatory mapping has become an integral part of participatory appraisal approaches and has greatly improved the understanding of indigenous communities' perception of their environment, particularly with the integration of Geographical Information Systems (GIS) (Tripathi and Bhattarya 2004). The inclusion of community perceptions was aimed at reducing the misconception by 'outsiders', such as researchers who perceive the indigenous community environment using their own 'mental filters' (Herlihy and Knapp 2003).

In the pastoral resource use context, the herders' spatial knowledge aid them in recognition of resource heterogeneity within their territory and this understanding is important for the management of daily and seasonal livestock mobility (Fernandez-Gimenez 2000; Schareika 2001). The herders' spatial knowledge of their territory received recognition for its potential in environmental management, particularly for its application in ecological classifications and environmental assessment either separately or integrated with scientific approaches (Bollig and Schulte 1999; Oba and Kaitira 2006; Roba and Oba 2009; Verlinden and Dayot 2005). Other studies, using ethno-ecological approaches, described indigenous communities' perception of their territories by identifying landscape units based on habitat types (e.g., Krohmer 2010; Molnar 2012). However, in these studies, differentiation of landscape units was still done based on ecological criteria and did not focus on how resource users characterize their grazing areas into use-related spaces and the mental representation of their territories.

Mental representations are observers' perception of the real world, hence a subjective understanding by the observer (Imani and Tabaeian 2012; Schenk 2013). Lynch (1960) noted that mental images resulted from two aspects: the environment and the observer, where "the environment suggests distinction and relations, the observer with great adaptability and in light of his purpose—selects, organizes and endows with meaning what he sees" (p. 6). It is further emphasized that mental maps consist of other details such as social relations, histories, and recollections associated with those environments (McKenna et al. 2008; McLain et al. 2013). Thus, mental maps are regarded as an essential element in organizing and storing knowledge on resource availability, to communicate this spatial information and to use it in decision making (Kitchin 1994; Tuan 1975).

This is of interest particularly when considering Bateson's (1983) explanation of the importance of *differences* for cognition. Bateson had used the analogy of the map and the territory, and asked "what is it in the territory that gets onto the map?" If the territory were uniform, nothing would get on the map. What gets onto the map in fact is difference. What constitutes "difference" is defined by the observer and not by the object (Wilke 1994:24). Hence, we can assume that rangeland properties that pastoralists perceive and use to characterize their grazing areas are differences that are related to their production purposes, and are important in their resource management.

This paper aims at reconstructing Borana pastoralists' 'mental maps' of their rangelands. The objective of the paper is to elucidate what differences the pastoralists recognized in their rangelands, what criteria they use for differentiating parts of the rangelands in relation to grazing use, and how based on these they structure their territory. The study also relates pastoralists' recognized characteristics of the rangelands to the assessed ecological attributes, such as occurrence of desirable fodder varieties. The study uses a comparative approach by considering three pastoral zones of the Borana rangelands in southern Ethiopia.

Methods

Study Area

The Borana rangelands of southern Ethiopia cover an area of about 95,000 km^2 (Fig. 1) with altitude ranging from 500 to 1500 m above sea level (Coppock 1994). Rainfall is bimodal (long rainy season, *ganna* from March to May, and short rainy season, *hagaya* in October–November) and varies from 250 to 1000 mm annually (Coppock 1994; Helland 1980). The Borana predominantly rear cattle but the numbers of small ruminants and camels are on the rise (Megersa et al. 2014). The Borana range is a tropical

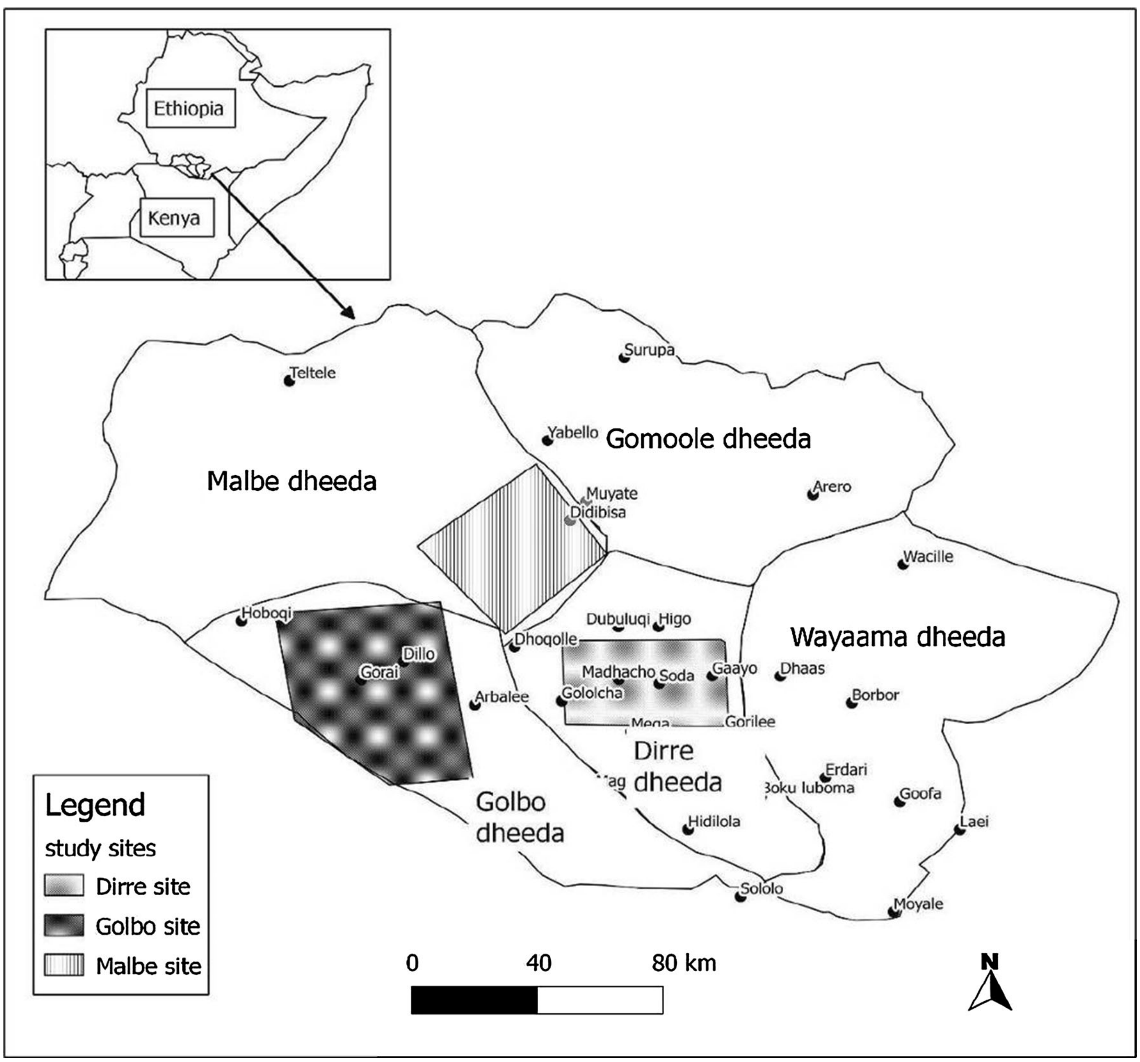

Fig. 1 Location of the study sites within the Borana zone, southern Ethiopia

savannah vegetation, originally open grasslands but taken over by acacia bushes (Coppock 1994; Dalle et al. 2006). Rainfall variability, differences in soil types, and variation in latitude within the rangelands creates dissimilar landscape types (Coppock 1994; Cossins and Upton 1988).

The Borana pastoralists divide their rangelands into two broad regions: the *Dirre* and *Liban*. The regions are further reclassified into zones called *dheeda*, differentiated by altitude and rainfall variation. *Liban* region has two *dheeda*, *Golba* and *Dida*, while Dirre has five *dheeda*, which include *Wayaama*, *Golbo*, *Dirre* (with *tula* deep wells), *Gomoole*, and *Malbe* (Oba 1998; Oba and Kotile 2001). *Wayaama* is located to the East and is characterized by red soil, warm conditions and is regarded an important wet season grazing area. *Golbo* is the lowlands situated to the southwest towards the border with Kenya and is associated with gray soils and black boulders of volcanic origin, suitable also for wet season grazing. The *Dirre* zone is where clusters of ancient *tula* wells are located. This zone is characterized by open savannah grass lands with a variety of perennial grasses, permanent water sources, and is preferred for dry season grazing. *Gomoole* lies towards the north and is characterized by sub-humid conditions, and the *Malbe* is situated towards northwest, characterized by undulating hills and adjacent lowlands (Angassa and Oba 2007; Oba 1998). Within the *dheeda* are units called *madda* comprising permanent water sources and associated grazing ranges, which further encompass smaller sub-units of resource users called *arda* that are a collection of villages (*olla*) (Homann 2004; Helland 1980; Kamara et al. 2004; Oba and Kotile 2001; Coppock 1994).

Selection of the Study Sites

In this study, three *dheeda* of *Dirre*, *Malbe*, and *Golbo* (Fig. 1) were selected from the Dirre region with no site selected from Liban due to logistical limitations. The selection considered ecological gradient and pastoralists' perceived bio-physical differences. In this respect, the three selected *dheeda* are regarded representative of the Borana rangelands. The *dheeda* of *Gomoole* and *Wayaama* were not selected due to the dominant practice of agro-pastoralism in *Gomoole* and intermittent ethnic conflicts in *Wayaama*. From each of the three selected *dheeda*, two adjacent *madda* were selected based on accessibility. From *Dirre dheeda*, Madhacho and Soda *madda* were selected, from *Malbe*, Haraweyu and Gobso were selected, while Dillo and Gorai *madda* were considered from Golbo *dheeda*. *Madda* was chosen as a unit of study because it is the Borana pastoralists' basis for resource management, with identifiable resource borders and associated users (e.g., Coppock 1994). The study was conducted between January–March 2012 and December 2012–August 2013.

Data Collection

Participatory Mapping of Grazing Areas

Participatory mapping was conducted to identify and characterize grazing areas at *madda* level. Google earth image printout covering the geographical extent of two selected adjacent *madda* per *dheeda* was used as a visual aid in the participatory mapping. The image was printed on tarpaulin material of about 1.5 m × 2 m at a scale of about 1:15,000 where topographical features such as mountains, water courses, roads, and vegetation are visible.

We conducted 3 mapping sessions per *madda*, each involving 8–10 participants. The mapping participants were identified with support of village elders based on their knowledge and herding experience, as well as familiarity with the grazing areas. The mapping sessions were conducted using the native language of the participants (*afaani Borana*).

Using selected features as reference, the participants identified locations of all settlements in their *madda*. Settlements were easy to locate due to visibility of homestead structures in some cases and unique brown colouration on the map that differentiates it from other areas. The participants were then asked to identify the location and name grazing units on the satellite image. They were further asked how the different individual grazing units can be differentiated from one another. The questions asked included how does someone herding know that he/she has crossed from one of the named grazing unit into the next? What identifies the borders? Can you identify the features on the map that can be used to tell where one unit ends and the next begin? The herders, based on their spatial knowledge of the areas, provided detailed descriptions of features associated with each of the grazing unit in relation to their grazing use. The participants then delineated adjacent grazing units from each other by drawing dotted lines from one feature to another, and in few instances where features were not visible, estimations based on knowledge of ground distance from recognizable features were used.

The participants were further asked to identify areas of seasonal livestock grazing by aggregating the individual grazing units. The participants detailed the characteristics of each seasonal livestock grazing area that include soil color, extent of woody cover, main grass varieties, and prevalence of ecto-parasites. Based on the current status of the above characteristics, they also discussed and ranked the grazing suitability of the aggregated seasonal grazing areas as either most suitable, suitable, or least suitable for cattle grazing in each study site. The total area mapped, which encompassed the two adjacent *madda*, was approximately 50 km × 30 km in Dirre, 48 × 40 km in

Malbe, and 66 km × 50 km in Golbo. The maps were presented to other herders not involved in the mapping exercise for verification and further inputs. Location of villages and water points were also recorded using a hand-held GPS device during the field work period.

Assessment of Occurrence of Fodder Species for Cattle in Seasonal Livestock Grazing Areas

We used the dry weight rank method (Mannetje and Haydock 1963) to assess the occurrence of fodder species for cattle which the pastoralists indicated to be typically found in the different seasonal grazing areas. The method was originally developed for the perennial grasses of Australia but has been used and shown to work well for assessment of pastures in tropical, sub-tropical, and temperate areas (Jones and Hargreaves 1979), for tall grass prairie (Gillen and Smith 1986) as well as annual grasses (Ratliff and Frost 1990). Mannetje and Haydock (1963) argued that the method is not suitable for pastures where one species consistently comprise more than 70 % of the composition, but this was improved by Jones and Hargreaves (1979) using a 'cumulative ranking' approach where a species is allocated more than one rank if its share exceeds 75 %. We selected the method because it provides a fast and non-destructive way of estimating the contribution of individual species to the total herbage mass over expansive areas. In this method, quadrats are placed randomly in a pasture and all the species within the quadrat are listed, and the observer visually identifies and ranks the three species that contribute the most to the dry weight. Then, the proportion of quadrats in which a given species obtained ranks 1, 2 or 3 is computed by dividing the counts of each rank by the number of quadrats assessed. To estimate the percentage dry weight of each species, the proportions of the three ranks are multiplied by standard multipliers (70.69, 20.9, and 8.4, for proportion of the ranks 1, 2, and 3, respectively) and summed. The standard multipliers were developed by Mannetje and Haydock (1963) in a calibration process. They first ranked the species within a set of quadrats on the basis of their estimated contribution to the total biomass and then harvested, sorted, dried, and weighed the herbage. Using regression analysis, the actual percentages of weight composition obtained from this clipped herbage were compared with the proportion of quadrats where the species were ranked 1, 2 or 3. To calculate the multipliers, they use the equation

$$P_i = k_1X_{1i} + k_2X_{2i} + k_3X_{3i},$$

where P is the percentage dry weight composition; i identifies the species; X_1, X_2, and X_3 are the proportions of quadrats in which the species was ranked 1st, 2nd, and 3rd, respectively; and k_1, k_2, and k_3 were the multipliers for the respective ranks. The sum of P's for a sample must equal to 100; hence, the model was designed such that the sum of k_1, k_2, and k_3 equals 100.

We conducted the vegetation assessment in the different seasonal grazing areas in each *dheeda*. Given that the study areas were located in remote area, access to the grazing areas for such assessments was only possible via small motorable paths. These paths are not regularly used as they do not link the main centers or lead to water points. However, during sampling, the transects were placed 500 m off the paths to eliminate any possible effects from the path usage. An assessment along such paths was also done by Oba and Kotile (2001) and Roba and Oba (2008) working in similar conditions. The sampling start point, within each seasonal livestock grazing area, was decided by moving 1 km inside the target grazing area from its boarders, which was identified by the senior herders. Transects were placed perpendicular to the paths with each subsequent ones placed on alternating sides and at 500 m intervals. In each area, 10 transects were laid over a distance of about 4.5 km, except in two areas where the terrain did not allow. Each transect was 200 m long and along each, we sampled 5 (1 m × 1 m) plots at 40 m intervals. Similar sampling methods were also used by Oba et al. (2000) and Roba and Oba (2008). In each plot, with the help of the 4 herders, we identified and recorded local names of all the herbaceous plant species. For each of the identified species, the herders indicated the desirability by cattle, as either 'very desirable', 'desirable', 'partly desirable' or 'undesirable'. We specifically focused on fodder for cattle because they are the dominant livestock species in the Borana rangelands (Megersa et al. 2014). The desirability categories were based on the herders' knowledge of fodder selection by cattle where 'very desirable' is the species selected first when grazing, while on the other hand the 'undesirable' is never ingested. 'Desirable' and 'partly desirable' are selected when very desirable fodder is exhausted in that order. Together with the herders, three species with estimated highest biomass contribution were identified and ranked. In each area, a total of 50 (1 × 1 m) sampling plots were assessed except in two areas, where only 35 plots were assessed due to inaccessibility of the terrain. Overall, a total of 420 plots were sampled.

Data Analysis

The community-drawn grazing unit map was geo-referenced by initially transferring the boundaries of the grazing units, as drawn on the GE printout by the community participants, onto the Google earth image on screen. Then geographic references of three visible features located towards the periphery of the map were recorded. The image was saved as JPEG and loaded onto ArcGIS 10.2, and geo-referenced using the coordinates of the three points marked on the image as reference points. The grazing unit borders on this geo-referenced image were re-traced onto overlaid shape files as polygons and attributes recorded in the attribute tables. The features within the grazing unit, such as seasonal and permanent water sources, villages, trading centers, and roads, were also digitized while cross checking with the points taken on the ground using hand-held GPS device. The area of each grazing unit was calculated using the GIS geometric tools. Criteria used for differentiation of grazing areas such as soil color, landforms, vegetation type, and manmade features were described to understand their importance in influencing resource properties and use.

In order to get the proportion for the single vegetation species over the 50 sampled plots, we first summed the number of times a given species was assigned each of the three ranks (e.g., 1st rank: 5; 2nd rank: 2, 3rd rank: 7). The sum of each rank for a species was then divided by the total number of plots sampled in each of the sites, to get its proportion (e.g., 5/50; 2/50, 7/50). Each proportion obtained for the first, second, and third rank was multiplied by the factors 70.69, 20.93, and 8.38, respectively, and summed (e.g., $5/50 \times 70.69 + 2/50 \times 2.93 + 7/50 \times 8.38 = 9.08$) to obtain the dry weight proportion of each species (e.g., Mannetje and Haydock 1963). A total of approximately 35 grass species and 60 other forbs species were documented (Appendix 2 in Electronic supplementary material). Spearman's correlation test (in SPSS version 20) was conducted to establish the relationship between the suitability ranks of the seasonal grazing areas provided by the herders and the estimated dry weight proportions of desirable fodder varieties which were recorded during the assessment.

Results

The participatory mapping in each *madda* revealed single grazing units, and at an aggregated level, a category called "seasonal grazing areas" was differentiated by the Borana herders. These seasonal grazing areas, which encompass several grazing units, were differentiated using a number of factors that determined the suitability for livestock grazing in different seasons, while the names of these areas mainly derived from the dominant soil color.

Grazing Units' Identification

The total area mapped, encompassing six different *madda* from the 3 *dheeda*, covered approximately 4000 km^2. In the overall 18 mapping sessions conducted, the participants differentiated a total of 151 single grazing units (Fig. 2). The herders identified the grazing units using features such as hills/mountains, water courses, and paths that pass through or along the sides of the area as well as village locations. While some of these features were visible from the Google earth image, the herders described most of them by recalling from their mental representation of the units. They used consensus to demarcate where one unit ended and another began. All the spaces in each *madda* were fully mapped, with grazing units identified ranging in sizes from 3 to 120 km^2. The resulting map showed the single grazing units that were of different shapes, the position of the settlements, and that of seasonal and permanent water sources (Fig. 2, detailed characteristics of each grazing unit is in Electronic supplementary material Appendix 1a–c).

Although the total grazing area mapped was smallest in Dirre (Table 1), the herders differentiated a similar number of grazing units in this *dheeda*, which are therefore smaller in size (Fig. 2). Furthermore, Dirre has the highest settlement density, resulting in higher population pressure compared to the other *dheeda*.

Naming of the Grazing Units

Herders differentiated the single grazing units using a number of criteria, the main criteria being reflected in the names of these units (Table 1). Grazing unit names mostly consisted of two words (binomial) that combined different criteria. Landforms and vegetation used either in combination or separately were the most often used criteria in naming (Table 2). Examples of such unit names are 'Gaara bisiqa' (the mountain with *Terminalia orbicularis*), 'Kuphi Ergemsa' (the hills with *Asparagus africanus*), 'Qaa adee' (the depression of *Salvadora persica*), and 'Bulee aroreesa' (the area with boulders and *Grewia bicolor*). Other grazing units were named after manmade features, for example, 'Onaa Ungaa' (the former settlement site of Ungaa), 'Dhoosa ireesa Chorre' (the depression of Chorre's grave), or (formerly) prevalent wildlife species such as 'Basa nyenchaa' (thickets of *Panthera leo*) and Urufee goljaa (the soft soil place of *Phacochoerus africanus*), while a few names were not associated with any features. Within one *madda*, all grazing units had different names, but grazing units with the same name were found in the different *madda*. The use of a criterion in naming grazing units were counted independent of whether used as first name or as second name in combination with others. Hence, the count of grazing units against the criterion used for naming (Table 1) is more than the total number of grazing units mapped in each study site. The names are given at the community level and have been in use for generations. Nevertheless, units have been re-named especially as shown by naming after manmade features such as grave sites.

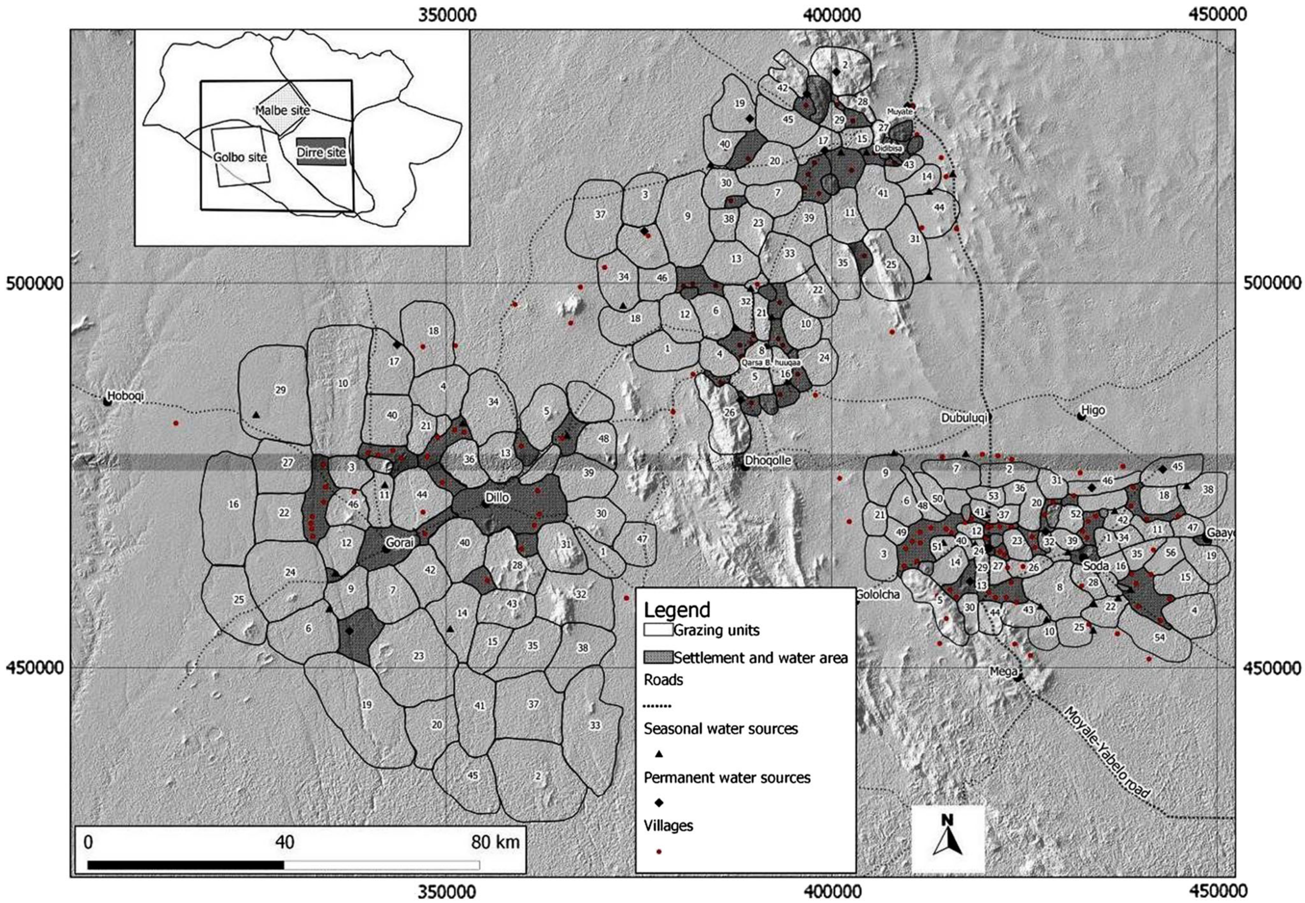

Fig. 2 Geo-referenced single grazing units delineated by Borana herders (*inset* the location of study sites within Borana zone, southern Ethiopia

Table 1 Summary showing properties of the mapped area

Pastoral zone (*dheeda*)	Total area mapped (km^2)	Number of settlements	Average area per settlement (km^2)	Number of grazing units identified	Total area of the grazing units (km^2)	Grazing units' proportion of total area mapped (%)	Average grazing unit sizes (km^2)
Dirre	942	61	15.4	56	770	82	14.0 ± 8.7
Malbe	1415	38	37.2	47	1172	83	25.5 ± 13.4
Golbo	287	28	92.4	49	2272	88	47.3 ± 27.1

Borana Herders' Criteria for Characterization of Grazing Units and Seasonal Grazing Areas

The Borana herders' criteria for the characterization of grazing areas can be broadly categorized into two: criteria that relate to physical attributes of the land such as landforms, vegetation, and soil; and those that were not directly related to land physical attributes such as (former) prevalence of wildlife species, anthropogenic factors such as water points and previous settlements sites, and prevalence of ecto-parasites. The criteria's use in the characterization was in relation to associated grazing properties as detailed below.

Land-Related Physical Criteria Used in Grazing Area Characterization

Landforms Landforms were the main features for differentiating and naming grazing units (Table 2) by the Borana herders. The different landforms have differing grazing resource endowments and resource properties. These landforms, through their natural occurrences, lead to a

Table 2 Criteria used by the herders to name the grazing units

Criteria	Sub-criteria	Sub-criteria local name (examples)	Number of grazing units named after each sub-criteria in the respective study sites			Percentage of units named using the criteria (%)
			Dirre	Golbo	Malbe	
Landform	Mountain	*Gaara*	4	12	7	51
	Hill	*Kuphi*	2	8	3	
	Slight ground elevations	*Kukuba*, *dirra*, *gooro*, *dudaa*	5	1	2	
	Volcanic stones	*Bulee*, *carii*	3	10	2	
	Large rock surfaces	*Qarsa*, *dhaga*, *Boralee*	5	2	6	
	Waters courses	*Lagaa*, *malkaa*, *qaa*	5	6	1	
	Depressions	*Dhoosa*, *dambala*,	8	5		
	Area between hills	*Goda*, *kaarra*, *dhibu*	2		2	
	Volcanic crater	*Booqe*	1			
	Ant hills	*Kooba*		1		
Soil color	Red	*Wayaama*	1		1	2
	Black	*Kooticha*	1			
	sandy	*Ramaata*			1	
	Soil texture (loose)	*Uruffe*			1	
Vegetation	Dominant woody species	Single species names	14	8	11	27
	Extent of woody cover	R*aasa*, *badda*	2	1	5	
	Absence of woody cover	*Diida*	5	6	2	
Manmade features	Previous settlements	*Onaa*, *teeso*	2			9
	Cleared patch	*Ciraa*		1		
	Burial sites	*Ireesa*	2	3		
	Water pans/wells	*Hara*, *elaa*	7	1	4	
Wildlife species	Name of wildlife species (formerly) prevalent in the area	*Basa nyencha* (Lion's thicket)	3	2	2	3
Natural water source	e.g., spring	*Maddo*		1	1	1
	Grazing units with names that do not have specific meaning	e.g., *Daaga*	3	1	8	6
Sum			75	69	59	

specific distribution of the resources in the area. Additionally, these resources are available or suitable for access at different periods leading to a spatial–temporal heterogeneity of resource availability.

The landforms that differ mostly in resource properties are elevations and depressions. Elevations such as mountains and hills are usually used during dry seasons. The herders explained that this is due to the presence of grass species such as *Themeda triandra* (Gaaguroo), *Panicum ruspolii* (Sokorruu), and *Heteropogon contortus* (Seericha), which are perennial grass varieties that last into the dry season. Additionally, leave litter from fodder tree species such as *Rhus natalensis* (Daboobeessa), *Pappea capensis* (Biiqqaa), and *Terminalia brownii* (Birreessa), found on some of the mountains, adds to the dry season availability of fodder. They further also reported that mountains/hills are slower in desiccation relative to low-lying areas. Hence, fodder remains relatively greener for longer periods. Furthermore, as these areas are more challenging to access due to their elevated nature, they are mostly used after the low-lying areas are exhausted. On the other hand, slight elevated areas such as *gooro* (raised and elongated), *kukuba*, or *dirra* (slightly raised areas) were observed to be well drained, and herders emphasized the presence of early sprouting grass varieties such as *Sporobolus pyramidalis* (Bukkicha) and *Eragrostis* sp. (Samphillee), and therefore see them as important grazing areas during the early part of the rainy season.

Landscape depressions were characterized based on their shape and water retention capacities and are important for the dual purposes of providing water during rainy season and fodder resources during the dry season. For example, depressions such as *dhoosa* or *dambala* can impound rain water, while units named *qaa*, *laga*, or *malka* indicate the presence of water courses in the grazing unit that flow during rainy seasons and have limited water retention ability. After the rains, these places collect rain water but as they dry up quickly, they are the first to be utilized before retreating to other water sources such as earth pans and wells. Due to deposits of fertile soil from raised areas and its water retention capabilities, these areas support vegetation growth for longer periods. The herders described this property as '*fiil qabdi*', with the literal meaning 'oil patch on a fabric' to stress the persistence of its vegetation. Such units often contain patches of perennial grass varieties, which also have the ability to withstand repeated grazing and provide fodder into dry periods.

Soils The herders used the dominant soil color to identify and aggregate the single grazing units into seasonal grazing areas. Further, they used a combination of factors such as soil drainage properties, extent of woody cover, grass species found, and prevalence of ecto-parasites (Table 3) to describe the aggregated seasonal areas' suitability for cattle grazing in different seasons. In each study site, the herders aggregated the grazing units into three main seasonal grazing areas. In Dirre, they distinguished *lafa biye adii* (white soil area), *lafa kooticha* (black soil area), and *lafa wayaama* (red soil area) and in Malbe *lafa wayaama*, *lafa kooticha* and *lafa raamata* (sandy soil area). In Golbo, the main areas distinguished were *lafa gamooji* (the term refers to conducive conditions for livestock, the area has grayish soil with black volcanic stones), *lafa caari kooticha* (dark soil with pebbles), and *lafa girrisa maansa* (sandy with stony grits) (Fig. 3). Although it is acknowledged that the soil color is not uniform across the respective areas, the herders used dominant soil type as a common factor to identify the seasonal grazing areas. An important element of the soil that determined seasonal grazing was its drainage properties. The drainage property was reported to influence vegetation and the fodder types, as well as its quality and availability over time. Soils with poor drainage properties, such as *lafa kooticha*, pose physical challenges during rainy periods. Such soils are associated with grass species that can withstand repeated grazing such as *Pennisetum mezianum* (Ogondhicho) and *Cenchrus ciliaris* (Matagudeesa) supplying crucial feed into the dry seasons. Easily draining soils such as *lafa ramata* (sandy soils) and *lafa gamooji* are known for fast sprouting grasses, for example, *Eragrostis* sp. (Samphillee), *Aristida* sp. (Bilaa), and *Sporobolus* sp. (Bukkicha), and hence provide initial feed to enable livestock recovering from effects of dry periods.

The herders ranked the seasonal grazing areas' overall suitability for cattle grazing for each *dheeda*, using combination of these properties (Table 3). However, although they indicated grazing suitable of the areas in different seasons, the choice of the individual grazing units does not necessarily follow this. While aggregating the grazing units into the seasonal grazing areas, the herders still recognized the heterogeneity provided by factors such as landforms and vegetation that are further described below.

Woody Vegetation and Grass Varieties When differentiating grazing units based on woody cover, two properties were mainly observed (a) extent of woody cover; and (b) main woody species and their fodder value. Based on extent of woody cover, grazing areas varied from areas that are/were open (*diida*), with no or limited presence of woody cover, to those with extremely thick woody cover (*madhee*). The herders associated *diida* areas with a high variety of grass species and suitability for use during early wet season, due to the presence of early sprouting fodder varieties. According to the herders, however, *diida* areas are exhausted uniformly by repeated grazing. Currently, in the Borana rangelands, almost all the units identified with the name *diida* are bush encroached, showing that names are retained even when the unit property changes. Increase in woody cover was generally associated with decrease in suitability for cattle grazing. Extremely thick woody cover impedes herding due to physical challenges to movements. Additionally, they can provide habitat for wild carnivores that prey on livestock. Some wood species, such as *A. melliphera*, *A. reficiens*, *A. nubica*, and *A. Senegal*, were singled out as detrimental to grass growth. However, the presence of woody species such as *Grewia vilosa*, *Grewia tenax*, and *Grewia bicolor* was positively viewed because of their palatable leaves, both when green and as leaf litter during dry periods. Also these species have not been observed to negatively affect grass growth. Grazing areas with such woody cover accompanied by grass undergrowth are preferred for dry season grazing, because grass remnants under bushes (called *luqiisa*) are not uniformly depleted like the case with *diida* areas.

The herders identified grasses as the main fodder for cattle, while other palatable herbaceous species supplemented. The herders described fodder varieties in three main aspects: those that are soft and easy to ingest (*marra laafa*), those associated with high nutritious value (*marra dhama qabu*), and others that are 'sweet' (*marra miyaa*). Herders associate these properties with selection by livestock when feeding, and based on this classified fodder for cattle into categories of very desirable, desirable, partly desirable, and undesirable fodder (details in Electronic supplementary material Appendix 2). The distribution of fodder species was associated with soil properties which

Table 3 Herders' criteria for differentiating seasonal grazing areas in the three zones of Dirre, Malbe, and Golbo of Borana rangelands

Pastoralist zone	Seasonal grazing units	Herders' characterization criteria					Preferred season of use for cattle	Cattle grazing suitability rank
		Drainage	Estimate of woody cover	Presence of ectoparasites	Main grass species in the area mentioned by herders	Observed dry weight estimates of the main grass species (%)		
Dirre	Lafa biye adii (white soil area)	Very good	Sparse (*mukka qabdi*)	Moderate tick presence	*Chrysopogon aucheri* (Alalo)	17.9	All season	Most suitable
					Cenchrus ciliaris (Matagudeesa)	8.6		
					Digitaria milanjiana (Hidoo)	0		
					Sporobolus sp. *(*Bukkicha)	7.7		
	Lafa Kooticha—(Black with stone pebbles)	Poor	Moderately thick (*raasa*)	High tick presence, other biting insects	*P. mezianum* (Ogondhicho)	8.5	Dry season	Suitable
					Sporobolus sp. (Bukkicha)	0.6		
					C. aucheri (Alalo),	22.0		
					C. ciliaris (Matagudeesa)	7.8		
	Lafa wayaama (Red)	Very good	Very thick (*guddo raasa*)	High tick presence, biting insects	*C. aucheri* (Alalo)	6.8	Dry season	Least suitable
					Eragrostis sp. (Samphillee)	2.4		
					C. ciliaris (Matagudeesa)	0		
					Chloris roxburghiana (Hidoo lucoo)	6		
Malbe	Lafa wayaama (Red)	Good	Very thick (*guddo raasa*)	Moderate tick presence	*C. aucheri* (Alalo)	6.4	Dry season	Most suitable
					Digitaria milanjiana (Hidoo)	5.7		
					C. ciliaris (Matagudeesa),	2.0		
					Loudetia flavida (Seericha)	0		
	Lafa kooticha (Black with stone pebbles)	Poor	Moderatley thick (*raasa*)	High tick presence	*C. aucheri*,(Alalo)	5.4	Wet season	Suitable
					P. mezianum (Ogondhicho)	2.8		
					C. ciliaris (Matagudeesa)	1.4		
					Sporobolus sp. (Bukkicha)	11.1		
	Lafa ramaata (Sandy)	Very good	Extremely thick (*madhee*)	Moderate tick present	*Sporobolus* sp. (Bukkicha)	4.7	Wet season	Least suitable
					Aristida sp. (Bilaa)	3.4		
					Unidentified (Omorafisa)	0.4		
					Eragrostis sp. (Samphillee)	2.0		

Table 3 continued

Pastoralist zone	Seasonal grazing units	Herders' characterization criteria					Preferred season of use for cattle	Cattle grazing suitability rank
		Drainage	Estimate of woody cover	Presence of ectoparasites	Main grass species in the area mentioned by herders	Observed dry weight estimates of the main grass species (%)		
Golbo	Lafa gamooji (Gray with black volcanic stones)	Good	Very sparse (*Diida*)	No tick presence	*C. aucheri*,(Alalo)	3.8	Wet season	Most suitable
					Cenchrus sp. (Dilaleesa)	2.8		
					D. milanjiana(Hidoo)	4		
					Eragrostis sp. (Samphillee)	2.2		
	Lafa caari kooticha (Black with volcanic stones)	Poor	Extremely thick (*madhee*)	High tick presence	*C. aucheri*, (Alalo)	11.3	Dry season	Suitable
					C. ciliaris (Matagudeesa)	0		
					Themeda triandra (Marra salaa)	0.6		
					Eragrostis sp. (Samphillee)	0.6		
	Lafa girrisa maansa (Grayish sandy)	Very good	Very thick (*guddo raasa*)	Low tick present	*Eragrostis* sp. (Samphillee).	2.3	Wet season	Least suitable
					Sporobolus sp. (Bukkicha)	3.2		
					Aristida sp.(Bilaa)	0.2		
					Digitaria milanjiana (hidoo)	0.4		

were also used when aggregating grazing units into seasonal grazing areas. It was in this respect that we conducted vegetation assessment in the seasonal grazing areas to understand the relationship between fodder varieties mentioned by the herders and their relative abundance in estimated dry weight in the respective areas. The assessment showed that most of the grass species mentioned by the herders do occur in the respective seasonal grazing areas assessed (Table 2). However, a few grass species said to be found in some areas were not observed during the assessment e.g., *Digitaria milanjiana* (Hidoo), *Cenchrus ciliaris* (Matagudeesa), and *Loudetia flavida* (Seericha).

The assessment also showed that the seasonal grazing areas (Fig. 3) differed in their estimated dry weight proportion of the fodder categories (Fig. 4a–c). The Spearman's correlation (in SPSS version 20) showed that all the seasonal grazing areas in Dirre were positively associated with higher proportion of desirable fodder varieties at 90 % confidence interval, with *lafa biye adii* significant at 95 % confidence interval (Fig. 4a). Malbe's *lafa wayaama* and Golbo's *lafa gamooji* were the only ones associated with high desirable fodder varieties (at 90 % confidence interval, Fig. 4b, c) in these sites. The correlations between the proportion of the desirable fodder and the seasonal grazing areas were generally weak, with the σ values ranging from 0.27 to 0.3. This can be attributed to the small sample in relation to the expansive grazing areas and the existing heterogeneity. However, our observations were consistent with the herders' cattle grazing suitability ranking of seasonal grazing areas (Table 3).

Non-land-related Criteria for Grazing Area Characterization

Prevalence of Ecto-parasites Ecto-parasites that mainly featured in grazing area characterization were ticks (*Dermacentor* sp.) and some biting insects. The herders associated tick occurrence with certain soil types and biting insects with sub-humid areas around mountain slopes particularly during the rainy seasons. Ticks were viewed as disease causative agents, and grazing in areas with high prevalence was therefore avoided. *Lafa kooticha* areas were characterized as the most tick-infested area, with *lafa gamooji* of Golbo recognized for the absence of ticks. They further pointed out that the absence of ticks in *gamooji* area motivated livestock movements to the area especially during the wet season. They also observed that areas with long time presence of settlements are more likely to have

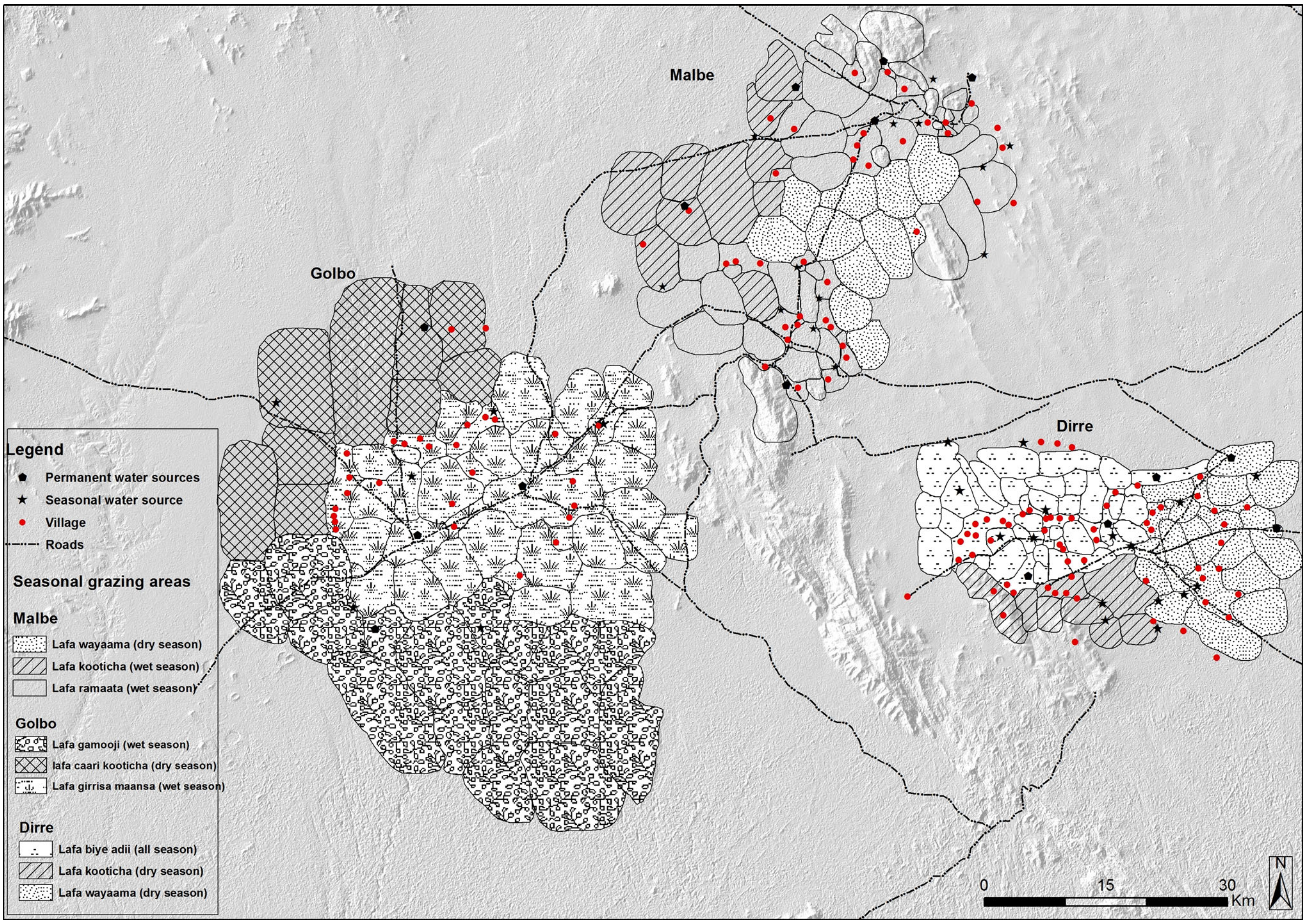

Fig. 3 Map of the study sites showing the grazing units aggregated into seasonal grazing areas

higher prevalence of ticks. Biting insects, viewed as irritants that affected feeding, were mainly associated with parts of Dirre with proximity to sub-humid mountains, where grazing during time of insect prevalence is avoided.

Formerly Prevalent Wildlife Species A few of the units bore names of certain wildlife species, indicating that these were or are prevalent in the area. The herders associated grazing units named after wildlife herbivores with good grazing for livestock, while those named after carnivorous species are often densely bushy and livestock grazed there risk predation.

Anthropogenic Factors Manmade features were used in characterizing grazing units that got their identity from human activities. Examples are units called *hara*, which indicate the long-term presence of hand dug earth pans in the unit. Such grazing units that also provide water access attract more livestock during the wet season because they are the initial choice before other permanent water sources are accessed. Abandoned settlement sites (*onaa/teeso*) are used to characterize grazing units. In these units, the vegetation is influenced by the nutrients from accumulated manure. The herders associated the grass variety *Cynodon dactylon (*sardo/arda), which is a preferred dry season fodder, with abandoned settlements sites.

Discussion

The purpose of this study was to obtain an understanding of pastoralists' perception and mental representation of their grazing areas at a scale relevant to their grazing use. It brings to light the differences that the pastoralists perceive and that they consider important in their livestock production endeavors and resource management practices. It locates these differences in resource availability geo-spatially. This is important based on the conceptualization that pastoral production environments are a social-ecological system with close interdependence between social and ecological aspects. Hence, neither the ecological system nor the social system can be adequately understood without

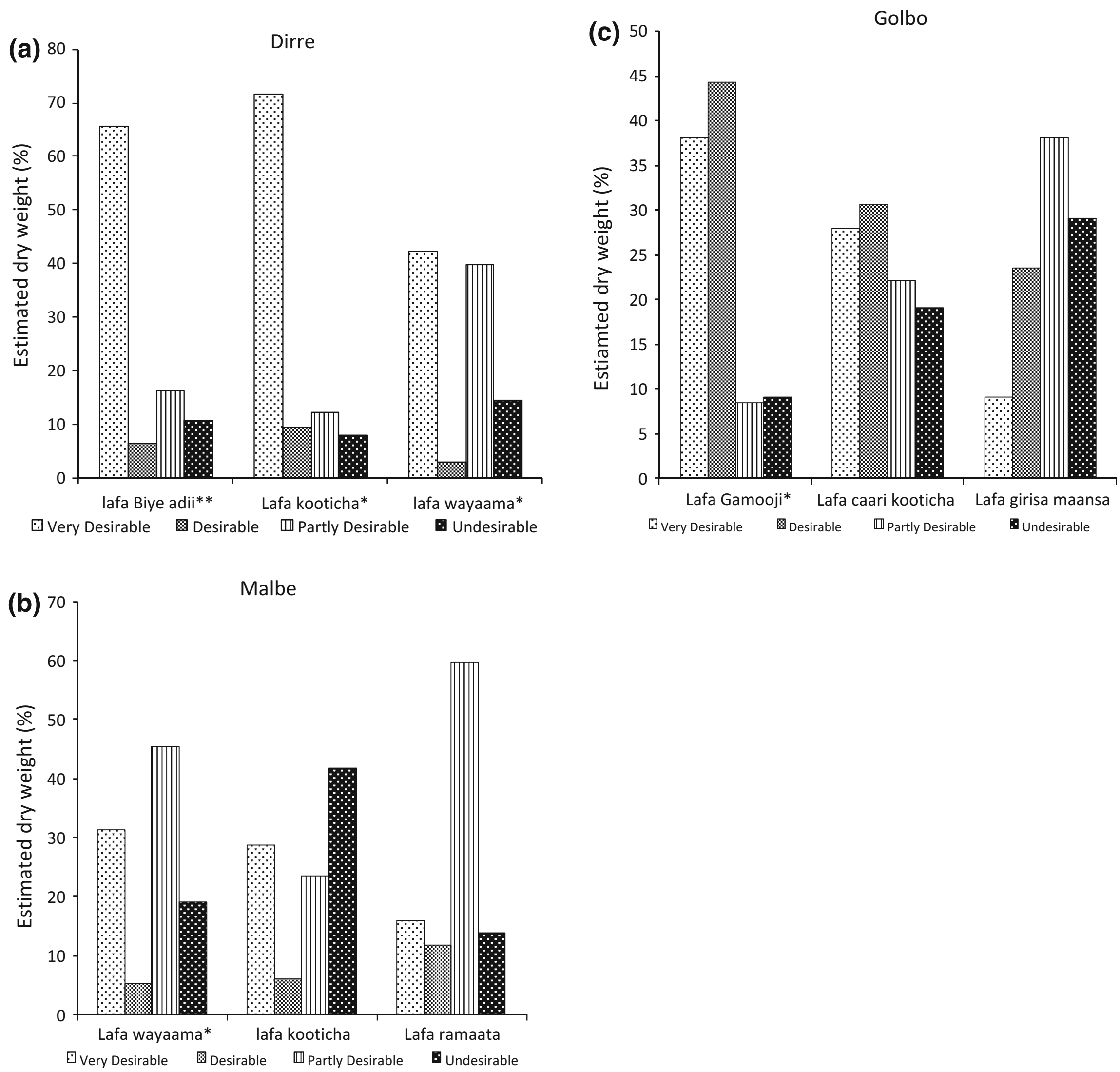

Fig. 4 Estimated dry weight proportions of fodder for cattle desirability categories in the respective seasonal grazing areas of **a** Dirre, **b** Malbe and **c** Golbo (**significant at 0.05, *significant at 0.10)

understanding the linkages between the two (Berkes and Folke 1998; Folke 2006; Ostrom 2009). This also means that in such a system, the ecological characteristics of the territory are highly dependent on the human decisions and active management practices in which herders with their animals continuously shape the landscape.

The grazing area differences perceived by the pastoralists are of importance because pastoral livestock production relies on the use of heterogeneous resources. Hence, the more heterogeneity the pastoralists perceive in the grazing areas, the more possibilities they have for selecting suitable areas at respective times (Kaufmann 2007). Pastoralists ideally make best use of the rangelands' transient resources by selecting areas with fodder that is above the average available within the rangeland (Kratli et al. 2013; Schareika 2001; Breman and de Wit 1983). This underscores that knowledge on the spatial location and the characteristics of the specific grazing areas is crucial for their grazing management as well as the ability to communicate the same within their communities.

Our approach made use of this spatial knowledge to capture how the Borana pastoralists differentiated their rangelands into grazing units with identifiable borders. Towards this endeavor, the use of Google earth images acted as visual prompt to locate and demarcate the individual units using the visible features, while the communities own mental maps of the area provided the details that distinguished the areas. The mapping process showed that there is consensus among the Borana pastoralists about the location and characteristics of the grazing units. In all the six *madda*, herders managed to map out the entire area based on their mental representation of the areas aided by the visual markers from the Google earth image. The single grazing units were different in sizes, ranging from 3 to over

100 km^2 and on average ranged from 14 km^2 for Dirre to about 50 km^2 for Golbo. The difference in sizes of the grazing units in the respective areas might be a reflection of the areas' intensity of use. The herders from areas assumed to be under higher pressure such as Dirre identified smaller grazing units, which is a possible adaptation to the reduced grazing spaces. This also suggests that it is possible for the larger units to be further delineated into smaller constituent units as their use intensifies. Studying Komi and Taz Nenet pastoralists, Istomin and Dwyer (2009) argued that detail richness of the mental maps depended on individuals' familiarity with the area and the communities' resource use system. For instance, they observed that the non-migratory Taz Nenet herders conceptualized the grazing areas as distinctive regions with names and clear boarders distinguished by specific features such as water sheds, while the migratory Komi herders had detailed mental representations of long stretches of areas along their migratory routes; and thus also relates to the observation that objects that previously appear similar are perceived differently as additional traits are recognized (Kaufmann 2007). The recognition of more differences increases the variability perceived which increases the selection intensity of the areas (ibid). Such mental maps of the perceived differences are important for planning and executing daily and seasonal livestock herding. Herding activities, backed by detailed knowledge of the grazing resources, have been argued to significantly increase feed intake by exposing livestock to areas with different grazing properties at different times (Meuret 2014a; Meuret 2014b; Schlecht et al. 2006; Turner et al. 2005).

Further, the recognition of the differences combined with the assigning of unique names to each grazing unit creates a common understanding of resource distribution among the community. Given that livestock grazing is a communal activity, a common understanding is important for communication of fodder use arrangements, such as deferment of sections of the rangelands, a common practice by pastoralists (Niamir 1990). At household level, this knowledge and the ability to communicate it are needed on a day-to-day basis because livestock herding does not only involve the herder, but also include senior people at home who provide guidance on which grazing areas the herd should access (see also Butt 2011). Apart from this inter-communal sharing, there is intergenerational transfer of this knowledge which has also been observed among other pastoral and non-pastoral communities (McKenna et al. 2008; Oba 2012; Aswani and Lauer 2006).

The characteristics used in naming of the grazing units are influenced by their physical properties that are visually recognized, so that their position can be located. Also since the names are often intergenerational, most of the features are permanent, with the exception of some that relate to vegetation and wildlife species whose occurrence was observed to have changed overtime. Importantly, the features such as landform, soils, and vegetation used in grazing area characterization relate to their influence on fodder availability. Similar findings were reported by Krohmer (2010) among the Fulani herders where different habitats are associated with fodder types and suitable time of access. These observations also relate to the relational aspects of resources (Bathelt and Glückler 2005) where the users identify features based on their utility for the livestock grazing in respective seasons. Furthermore, Bateson (1983) also argued that the differences regarded important are recognized and would get on to the map; in this case, the differences that matter are those related to grazing use. The herders' spatial representation of the various features and their associated resources are important for them to keep track of the status and possible changes in resource properties.

The Borana herders used a combination of different area properties to determine the suitability of grazing areas for cattle during different seasons. This suitability ranking reflects the potential of the area in enhancing livestock's productive performance. The pastoralists' perceived grazing suitability of the seasonal grazing areas was observed to match with the proportion of desirable fodder species encountered during the assessment. Seasonal grazing areas in Dirre, despite having high human and animal population pressure, had the highest presence of desirable fodder species. The dry weight proportion estimates for the fodder species in the seasonal grazing areas confirmed the prevalence of many, but not all, of the main grass species the pastoralists associated with the respective areas. Some species mentioned by the herders to be prevalent obtained 0 % in the dry weight proportion results. One reason for this is that the method only considers the three most prevalent species, which means that a species that may have made it to the 4th rank was not included in the estimation by the method despite its prevalence.

The mental mapping approach adopted by this study has generally been observed to be an important tool in visualizing spatial aspects of human-environment connections that are otherwise not easily discerned by an outsider (Rowley 2013; McLain et al. 2013). The integrating of such community participatory maps into GIS software provides an avenue for converting indigenous knowledge into a form that can easily be communicated to policy developers at various levels (Rowley 2013; Denniston 1994). This approach is important in overcoming the challenges associated with incorporating of the livestock keepers knowledge in decision making processes such as those aimed at enhancing resilience to climate variability in arid and semi-arid rangelands (IIED 2013). Such participatory maps can also capture community perception of threats to the rangeland, and the approach can synergize with other efforts that aim to involve local communities in range resource monitoring and conservation (Oba and Kaitira 2006; Roba and Oba 2009). Although it remains challenging to include aspects of social perceptions and histories in the representations of mental maps (McLain et al. 2013), the interpretive quality of such maps make them an important tool to understand the landscape views and environmental connections of the local people that are otherwise difficult to discern (McLain et al. 2013; Soini 2001).

Conclusion

In this study, we used participatory mapping with pastoral communities to understand their differentiation and characterization of grazing areas. This differed from previous rangeland classification techniques, which mainly used climatic zonation and vegetation differences as the basis for classifying rangelands. Through the use of a participatory method, which employed visual satellite image of the grazing areas, it was possible to depict part of the community's mental maps of their environments as geospatial maps. To the herders, therefore, rangelands are not just expansive grazing areas, but made of entities with names, and specific resources that vary in availability and quality over time. Also, besides being markers used for visual recognition of the grazing units, the unique combination of characteristics such as landforms, soil types, and vegetation types is seen as determinants of the grazing resource properties. The pastoralists' ranking of suitability of grazing areas matched with the presence of desirable fodder species found through ecological assessments.

The characteristics observed by the pastoralists are differences that matter and are presumed to be those that are important in their grazing management practices. We propose that rangeland classification and characterization based on pastoralists' own criteria form a better basis for understanding pastoral use of the grazing areas and their related decision making. Such knowledge is of importance since in these social-ecological systems, the ecological sustainability is highly dependent on the human decisions and active management practices. The use of the GIS tools transforms the herders' 'mental maps' into a 'living' document onto which information can be added to enrich it further or make amendments where needed. Since it can easily be shared, it also enhances knowledge integration between the local communities and development planners and can promote ownership of projects based on community appreciated rangeland values and use preferences.

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