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Using Participatory Mapping and a Participatory Geographic Information System in pastoral land use investigation: The impacts of rangeland policy in Botswana

Basupi, L V., Quinn, C H., Dougill, A J

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Sustainability Research Institute (SRI), School of Earth and Environment,
The University of Leeds, Leeds, LS2 9JT, United Kingdom

Tel: +44 (0)113 3436461
Fax: +44 (0)113 3436716

Email: SRI-papers@see.leeds.ac.uk
Web-site: http://www.see.leeds.ac.uk/sri

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Abstract

Since the 1980s, the spatial extent of communal grazing lands in Botswana have been diminishing due to rangeland privatisation and fencing linked to animal health policies. Spatial comparisons of pastoral land use transformations are particularly important where accessibility to grazing and water resources remains at the core of sustainable pastoralism policies. Moreover, achieving success in pastoral development research requires a sound understanding of the traditional pastoralists' information systems including the nature of pastoralists' indigenous spatial knowledge. This study explores indigenous spatial knowledge through participatory mapping and PGIS to understand and analyse pastoralists' grazing patterns, spatial mobility and the impacts of subdivisions and privatisation policies in Botswana's Ngami rangelands. The study used focus group discussions, historical analysis through key informant interviews, policy content analysis and participatory mapping exercises along with community guided transect walks. Maps produced provide insights into the traditional pastoralists' tenures, patterns of land use and impacts of rangeland policy on traditional livestock spatial mobility and access to grazing lands. Privatisation and rangeland enclosures has resulted in the restricted movement of livestock, overstocking of floodplains and riparian rangelands with some natural water pans which were critical for wet season grazing now inaccessible to local communities. We conclude that the integration of herders' spatial knowledge can be used to foster better articulation and understanding of pastoralists' tenures which are often lacking in the communal land administration systems. Such integration of methods could usefully contribute to sustainable pastoral land management policy toolkits in semi-arid rangeland environments capable of enabling decision making for Sustainable Land Management.

Keywords: Communal grazing Lands; Indigenous knowledge; Spatial mobility; Privatisation; Sustainable Land Management; Okavango Delta

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ABOUT THE AUTHORS

Basupi, L V., is a PhD candidate at the Sustainability Research Institute, University of Leeds, funded by the Government of Botswana and Botswana International University of Science and Technology. He holds an MSc in Environmental Science from the University of Botswana. Before joining SRI in 2014 for his PhD, he was an employee of the Government of Botswana in the Department of Lands for 5 years. His doctoral research involves investigating impacts of subdivisions of communal lands and pastoral system shifts on pastoral land use and livelihoods systems south of the Okavango Delta in Ngamiland District, Botswana. The research combines qualitative participatory methods with quantitative spatial analysis using a *Participatory Geographic Information System* (PGIS) to investigate the local dynamics of land use and pastoral systems.

Quinn, C H., is an Associate Professor in the Sustainability Research Institute, University of Leeds. She is an environmental social scientist with over 15 years of experience working on interdisciplinary projects in Africa and the UK. Her research interests lie at the interface between social and agricultural dimensions of environmental change and sustainability. Specifically, her focus is on the livelihoods, vulnerability and adaptive capacity of farmers, and their relationships with governance, ecosystem services and landscapes, and supply chains.

Dougill, A J., is Professor of Environmental Sustainability and Dean of the Faculty of Environment at the University of Leeds, UK. He is a dryland environmental change researcher who has developed research approaches that integrate a range of disciplines including soil science, ecology, development studies and environmental social sciences. He has expertise in leading the design and implementation of inter-disciplinary 'problem-based' research projects focused on sustainability issues at range of scales. His work has developed innovative research methodologies for using scientific approaches together with local participation to ensure locally relevant research outputs across dryland Africa.

1. INTRODUCTION

Policies, laws and regulations that govern communal grazing lands have important implications for the livelihoods of pastoral communities (Benjaminsen et al., 2009, Rohde et al., 2006, Chanda et al., 2003). In sub–Saharan Africa, the consequences are particularly significant (Galaty, 2013, Tache, 2013, Mwangi, 2007, Peters, 1994) as many countries have undergone or are undergoing rapid tenure transformations (Ho, 2014, Toulmin, 2009, Lebert and Rohde, 2007). The changes in statutory land tenure systems such as privatisation have interrupted pastoralists' capacity for utilising customary land rights by using traditional mobility strategies for coping with eventualities such as drought and disease incidences (Kaye-Zwiebel and King, 2014, Lengoiboni et al., 2010).

Pastoralism in arid or semi-arid lands is characterised by substantial spatial heterogeneity in land use, resource access, management regimes and the ways in which pastoralists respond to environmental constraints (Tsegaye et al., 2013). The management system must be responsive to variability and uncertainty. The survival of herds depends on the pastoralists' ability to move to better areas with remaining fodder availability (Vetter, 2005). Therefore, extensive spatial scales of exploitation become a prerequisite for a successful pastoral production system (Moritz et al., 2013, Notenbaert et al., 2012). As an adaptive strategy, mobility allows pastoralists to guard against temporarily variable environmental conditions (Ellis, 1995) and also access key resources (water and fodder) that are heterogeneously distributed (Kaye-Zwiebel and King, 2014). Pastoral systems are also characterised by high dependency on local knowledge. The spatial knowledge systems held by herders help them determine what the temporal and spatial distribution of resources might be in any given year and are

central to sustainable pastoral herd mobility (Oba, 2013). The rationale for herd mobility is reinforced by the recognition that drylands systems are non-equilibrial in nature and that resource sustainability is largely a function of spatial and temporal variability in rainfall and/or fire (Dougill et al., 2016, Kakinuma et al., 2014, Dougill et al., 1999).

While pastoral mobility is at the core of many livelihoods in African rangelands, traditional patterns of mobility are increasingly under threat (Oba, 2013). Since the 1970s, development interventions and agricultural policy changes have interfered with indigenous rangeland management institutions, notably the alienation of valuable grazing and water resources, curtailment of mobility, sedentarization of pastoralists, establishment of artificial water points such as boreholes and the imposition of formal administration institutions (Ho, 2014, Homann et al., 2008, Cleaver and Donovan, 1995). The push towards subdivisions and privatisation continue to undermine the nature in which pastoralists' grazing activities are organised and spatially distributed in communal lands.

In Botswana, the significant policy arrangements that have impacted communal rangelands are the Tribal Grazing Land Policy (TGLP) of 1975 (Magole, 2009, White, 1992, Childers, 1981) and the National Policy on Agricultural Development (NPAD) of 1991 (RoB, 1991). Largely influenced by the tragedy of the commons thesis (Hardin, 1968), both policies viewed traditional pastoral systems as destructive and hence responsible for land degradation and low productivity (Rohde et al., 2006, Cullies and Watson, 2005). The assumption was that the effect of unregulated communal grazing coupled with the perceived increases in livestock numbers was responsible for rangeland degradation and the consequences would, over time, become severe. Livestock needed to be regulated in line with ecological carrying capacity and the only

way this was to be achieved was through privatisation since it was assumed that communal land tenure arrangements fail to regulate pastoralists access to resources (APRU, 1976, RoB, 1975). In Ngamiland, fences were introduced from the late 1980s following the first phase of TGLP ranches allocated in 1981. Today, pastoralists find themselves surrounded by private ranches and disease control fences which bisect rangelands and separate communal pastoralists from critical grazing resources.

To date, only very few studies have offered integration of pastoralists' spatial knowledge, spatial comparisons and/or participatory mapping approaches and PGIS to analyse pastoral management systems and the impacts of such transformations as described above. Studies have emphasised the overarching need to generate spatial environmental knowledge regarding pastoralists' tenures and land use in order to develop the capacity of local communities and help governments to reconcile pastoral tenure conflicts and manage resources in dryland areas (Bennett et al., 2013, Lengoiboni et al., 2010, Turner et al., 2014). This study draws on participatory research methods and geospatial technologies to explore local indigenous spatial knowledge in understanding traditional pastoralists' spatial mobility and the impacts of subdivisions and privatisation policies in Botswana's Ngamiland district. The study provides important spatial information based on pastoralists' knowledge that could potentially be used to inform planning. Participatory mapping and Participatory Geographic Information System (PGIS) approaches emphasise the involvement of local communities to produce distinctive spatial knowledge of their communities (Smith et al., 2012, Dunn, 2007).

The aim of this study is to explore indigenous spatial knowledge through participatory mapping to understand and analyse pastoralists' grazing spaces and patterns of spatial mobility prior to the 1975 rangeland policy and after policy intervention. The

study objectives are to: (1) investigate the spatial extent of communal grazing, traditional patterns of transhumance and regulatory mechanisms to access grazing lands before the land tenure transformation to its current situation in Ngamiland District, Botswana; and (2) determine the current land use patterns and spatial impacts of rangeland policies on access to grazing and water resources as per the pastoralists' spatial knowledge.

2. MATERIALS AND METHODS

Participatory approaches were used to collect primary data in the 7 study villages between April and August 2015. The criteria for selecting the study sites were based on proximity to the ranches and/or veterinary cordon fences, cattle numbers and distance from the ranches so as to determine the impact along a gradient. The sites were categorised as follows depending on their locations: Toteng/Sehithwa/Bodibeng/Bothatogo *(located adjacent to the ranches and Lake Ngami: Lake villages),* Kareng (Western sandveld village) and Semboyo/Makakung (Northern sandveld or Setata fence villages) (see figure 1). Through the village leadership meetings, the participatory research methods to be used in the data collection exercise and how the findings will be shared with the community and other relevant authorities were explained.

2.1. Study area

The study area is located on the southern fringe of the Okavango Delta (Figure 1). Ngamiland was chosen because of the number of ranches (over 180) demarcated in

the district (both through the Tribal Grazing Land Policy (TGLP) of 1975 and the National Policy on Agricultural Development (NPAD) of 1991), which makes it relevant to the problem being investigated. Also because the Okavango Delta is host to a large diversity of natural resources, including wildlife, diverse vegetation and water resources, land fragmentation through veterinary cordon fences and protection areas to separate wildlife and livestock is prominent. The area is dominated by open low shrub and tree savannahs, vast sand veld, alluvium (along the rivers) and limited hard veld (Burgess, 2004, BRIMP, 2002). The climate is sub-tropical (semi-arid) with distinct hot, wet summers, and cold dry winters. Recorded average rainfall ranges between 450 and 550 mm (DMS, 2013). The distribution of rainfall over space and time is highly variable and is the most determining factor in grazing distribution (DoL, 2009). Field data collection was conducted around Lake Ngami and areas south of the Setata veterinary cordon fence, where the primary livelihood activity is subsistence pastoralism. Selection and use of natural resources, as well as diseases pandemics (both human and livestock), have influenced settlements and migration patterns (including configuration of kinship networks) of different ethnic groups along the Okavango Delta (Mbaiwa et al., 2008). Settlements have been largely confined to the margins of the permanent swamps. The sandveld area known as Hainaveld where the privatised ranches have been demarcated is located to the south of Lake Ngami.

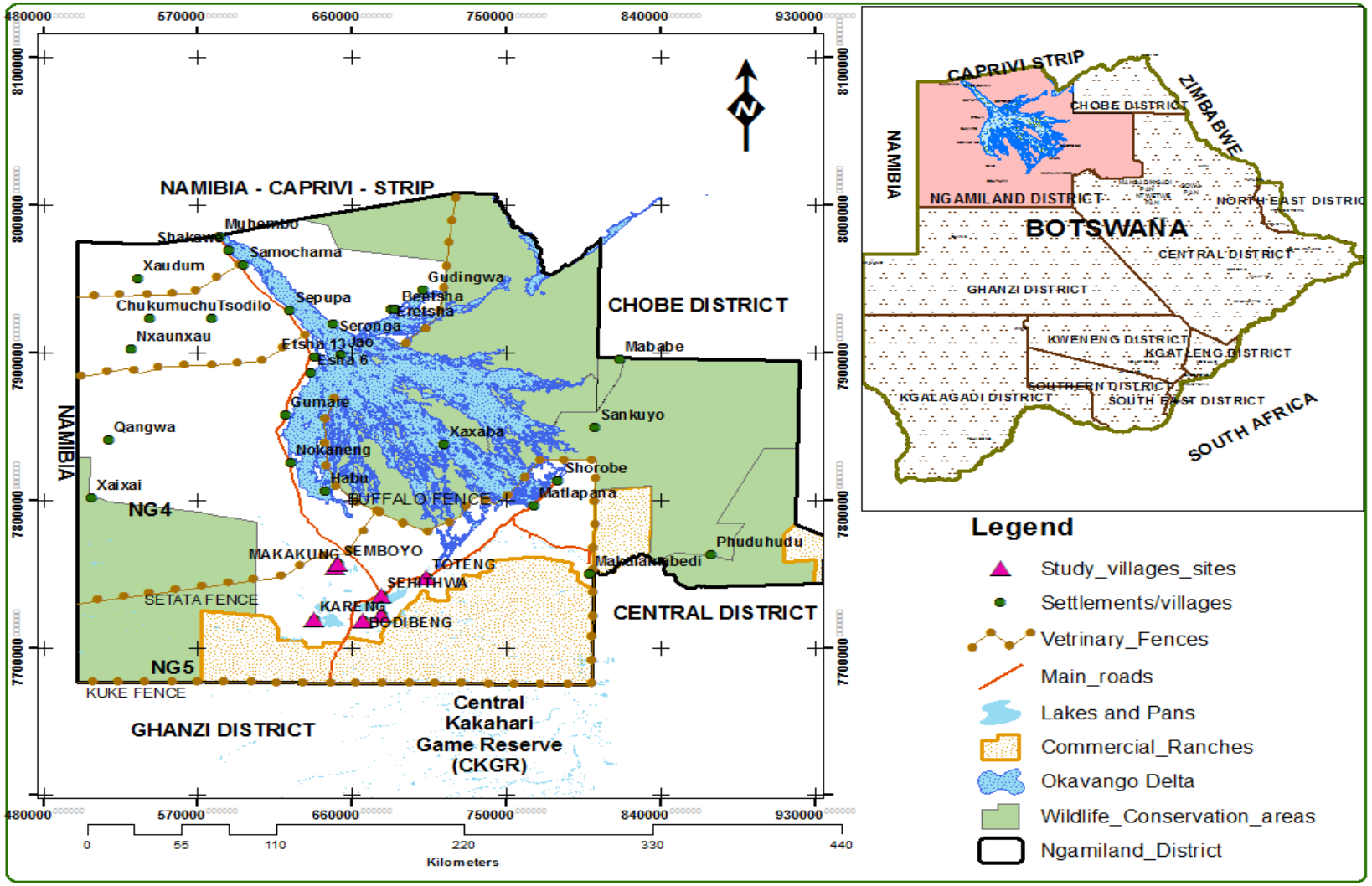

Figure 1: Ngamiland study area, its land uses and study sites Source: Authors

2.2. Focus group discussions

Focus group discussions (Hay, 2010) were conducted in each study village as follows, Semboyo *(n = 9)*, Makakung *(n = 12)*, Bothatogo *(n = 10)*, Bodibeng *(n = 8)*, Toteng *(n = 9),* Sehithwa *(n = 8)*, Kareng *(n = 6)*. Focus groups targeted different stakeholders and groups in the community, especially pastoralists (cattle herders) with experience in communal areas, members of the communal farmers' associations and farmers committees. Two additional focus groups targeted only women (a mix of female agro-pastoralists selected from the lake villages, *n = 14)* and youth groups (youth groups engaged in pastoral farming and those that were active in community projects, selected across the study villages, *n = 14)* to incorporate divergent views and also to avoid a situation whereby influential male members of a group dictate the mapping and discussion process. Farmers' committees, villages' leaderships and village development committees were used to solicit names of people who could participate in focus groups since they knew the people and were always available and willing to help. First they were, briefed on specifications for participants' required.

Discussions were structured around a set of questions on traditional mechanisms controlling access to communal lands, institutional forces governing patterns of spatial mobility, major changes in land tenure and pastoral land use arrangements since the early 1980s when fences were introduced, problems experienced in the communal areas and perspectives on current land tenure and land use. From this volunteers were identified who guided the transect walks and provided invaluable knowledge in the naming of places and landscape features. A total of 7 transect walks were carried out and the number of volunteers were as flows Semboyo *(n = 4)*, Makakung *(n = 6)*, Bodibeng *(n = 2)*, Bothatogo *(n = 6)* Toteng *(n = 3)*, Sehithwa *(n = 2)*, Kareng *(n = 4)*.

All interviews and discussions were conducted in *Setswana* language and tape recorded.

2.3. Participatory Mapping and PGIS

Using a cognitive mapping process (Chan et al., 2014), we utilised sketch maps drawn by farmers during the focus groups to determine the grazing areas, spatial extent and patterns of seasonal livestock mobility before and after the fences. Participatory mapping can form an important aspect of indigenous spatial knowledge generation (Chapin et al., 2005, Neitschman, 1995) since it allows resource users to convey not only positions of activities but also the background details concerning the locations and drivers of land use activities (Levine and Feinholz, 2015). The process involves using maps as spatial tools to acquire indigenous knowledge and portraying this in a spatial way through the use of GIS (Dunn, 2007, Talen, 2000). Indigenous spatial knowledge is the unique knowledge held by indigenous communities, acquired through practical experience and developed around specific geographic areas (McCall and Dunn, 2012). Pastoralists' maps can be fitted into the government cadastral classification to improve awareness of pastoralists' customary tenures and thus protect indigenous grazing lands patterns and transhumance corridors.

Participants were provided with two printed land cover base maps (Figure 2) at a spatial scale of 1:250,000. These maps were produced using data obtained from Department of Surveys and Mapping in the form of processed Landsat 8 imagery data running through 2013 (dry season; June and August) and 2014 (wet season; December and February). The classification was achieved using ArcGIS 'cluster unsupervised classification' whereby pixels are grouped using reflectance properties. Accuracies were improved by combining summer and winter data rather than single

data analyses. The map recorded different land cover categories; Dense Savanna / Forest, Open Low Shrubland, Cultivated Rainfed Crops, Swamp Vegetation (Bare and Low Herbaceous), Natural Bare Ground, Natural Waterbodies, Pans. In order to validate the land cover map, ground truthing was carried out over a period of two weeks of extensive field survey during the month of June 2016 (dry season). The field survey covered most of the accessible areas and landmark features such as natural water bodies or pans, rivers, plains and gravel roads used by pastoral communities in the study area. A Global Positioning System (GPS) was used to record all the coordinates of the features visited. Local volunteers assisted in the naming of landscape features; rivers, roads, pans and plains. The aim was to produce a base map to aid the participatory mapping process.

District land use data were obtained from various government departments; Department of Lands, Ministry of Agriculture, Department of Tourism and Tawana Land Board. Each department had a map to show its areas of interest and operation. For example, Tawana Land Board had general land uses while the Ministry of Agriculture had a more detailed map of agricultural land uses; cattle crushes, livestock boreholes and commercial ranches. These maps were compared and only those that provided the greatest detail of land uses were used. The land cover map was geo-referenced and then overlaid with land use data. This was to allow land use features such as roads, settlements and boreholes to appear on the land cover map so that participants could identify their grazing spaces around these features. The principal land features on the map that farmers could identify were the Okavango delta, swamp areas, Lake Ngami, roads, rivers, pans and pastoralists settlements and fences. Borehole data obtained from Tawana Land Board were also used to help focus group

participants in identifying grazing lands and cattle posts; borehole numbers were shown on the map and attribute data about the boreholes, such as names of owners, printed on a separate page.

Mapping sessions were conducted with each focus group. At the beginning, participants were asked to identify their settlements, prominent landscape features and to locate their grazing areas or cattle posts. Secondly, pastoralists were asked to delineate their historical pasture boundaries before the current fences, identifying them according to seasons. Based on their practical knowledge, participants were then asked to describe areas identified as grazing areas in terms of resources and access mechanisms. On a separate map showing the fences and ranches, participants were asked to identify their contemporary grazing spaces, including livestock movement patterns. The placement of a boundary or migratory movement patterns was achieved through consensus among group members. The degree of understanding of the map varied from one focus group to another. While some chose to depict their grazing areas as polygons, others chose to draw lines showing their migration to particular grazing areas. In order to validate features on participatory maps with features on the ground, community guided GPS transect walks were conducted with volunteers from each mapping group.

Results from the focus group discussions and participatory maps were checked for consistency by running a series of key informant interviews as well as by visiting cattle posts and conflicts prone zones. The purpose of key informant interviews was to collect information from a wide range of people with first – hand knowledge and experience of pastoral systems. The selection of key informants was based on purposive/judgemental sampling, which is the deliberate choice of an informant due to the qualities the informant possesses (Tongco, 2007). Members of different

committees; farmers committees, village development committees and pastoralists in cattle posts, were consulted to provide an initial list of potential respondents. Subsequent informants were identified through snowballing technique (Speelman et al., 2014, Denzin and Lincoln, 2000) .Participants were asked if they knew of others who meet the selection criterion and could potential participate in the interviews. A total of 26 informants were interviewed across the study area.

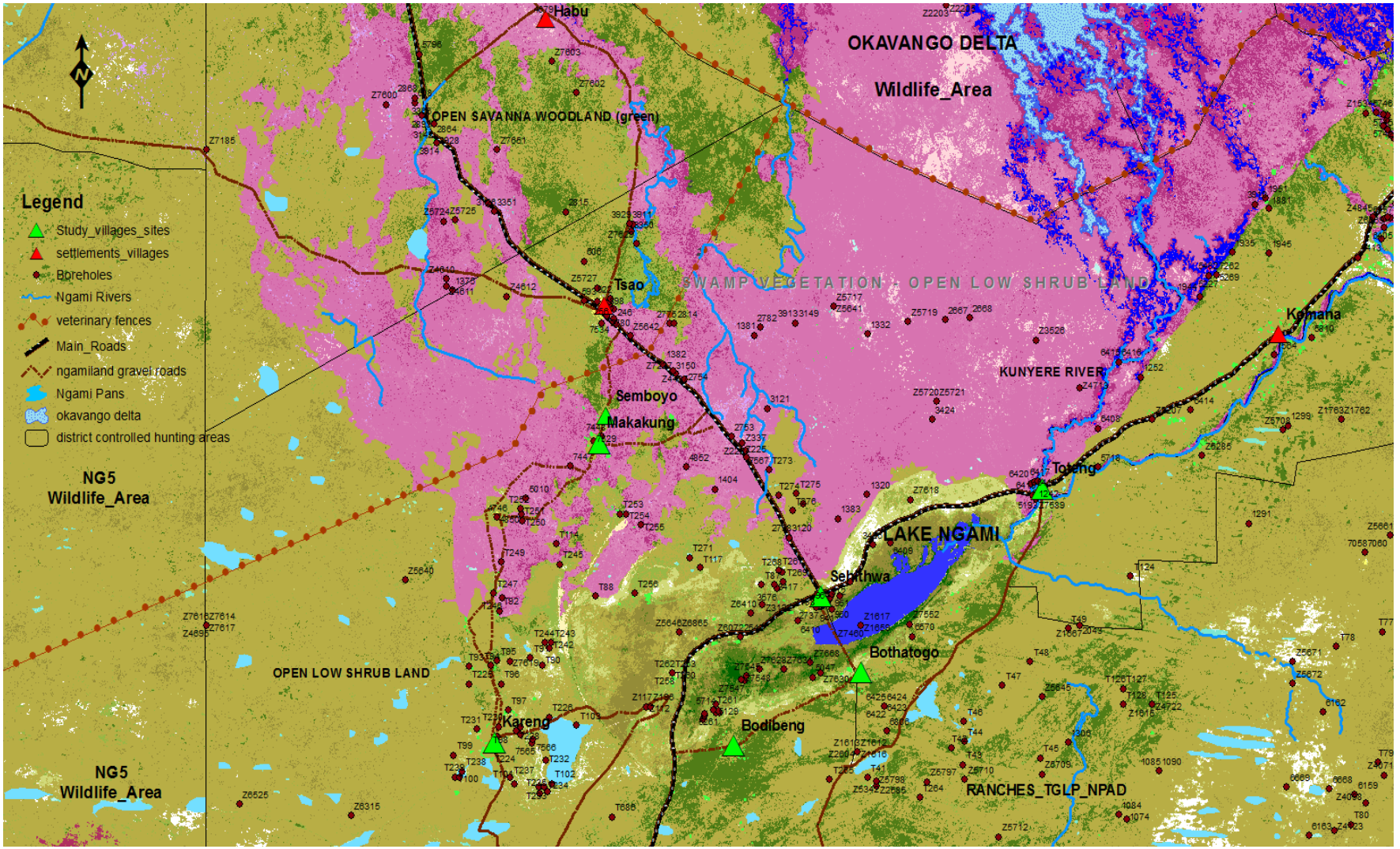

Figure 2: Landcover base Map Source: Authors Data Source: Department of Surveys and Mapping, Tawana Land Board, Landsat 8 satellite imagery

2.4. Data analysis

Maps made by local pastoralists were scanned and transformed into digital versions using ArcGIS software. In order to align the coordinates, locations and other topographic features, participatory sketch maps were geo-referenced using the base maps and district land use maps. These were then digitised into layers of digital polylines or polygons delimitating the full extent of boundaries identified by participants or pastoralists impressions of livestock movement patterns before and after the barrier fences. Maps from the different villages were overlaid to produce a consolidated map. The aim of the mapping exercise was to depict the landscape scale picture of the pastoral production system in terms of time and space as per the herders' spatial knowledge. These were then visualised in ArcGIS as PGIS maps. Land use pressure zones were identified using proximity and geographic distribution analysis through spatial statistics; mean centre and standard distance in ArcGIS (Scott and Janikas, 2010). First we identify the mean centre (the centre of concentration) for the land use features (cattle posts and arable lands). Standard Distance was then used to measure the degree to which these features are concentrated or dispersed around the mean centre, giving a spatial picture of the concentration of land use pressures.

Qualitative data from focus group discussions and key informant interviews were transcribed and analysed using content analysis in order to identify the main themes or issues emerging from the discussions. The content analysis involved the following steps: (i) identification of major themes emanating from the discussions (ii) assigning codes to major themes (iii) classification of responses under the identified themes (iv) writing the research narratives and discussions (Adam et al., 2015).

Policy content analysis of the two policies (TGLP and NPAD) was undertaken to uncover how these policies came about, the intended and unintended benefits and/or impacts, and how the policies are understood by the local pastoral communities. This were analysed along with data from in-depth interviews with key informants.

3. RESULTS

This section presents the results of the study based on the study objectives. The section starts by examining the traditional pastoral systems and grazing zones before the land tenure transformations. Attention has also been given to the historical and institutional forces governing patterns of spatial mobility, resource access and use. This formed the basis from which the spatial impacts of the transformations were studied and spatial comparisons of the past and present made**.**

3.1. Grazing zones before the land use transformation

In the extensive indigenous grazing lands before the current land tenure and land use transformations, pastoralists identified three distinct grazing zones (Figure 3) according to characteristics of grazing resources, indigenous management systems and seasonal livestock movement patterns. These zones are consistent with the indigenous management system of rotating livestock between main permanent water sources and remote grazing lands in the sand veld areas (Magole, 2009). The identified grazing zones are as follows: (1) Village grazing areas: these formed a radius of about 15 – 20 km around the main settlements. These grazing lands were

reserved for milk cows, smaller calves and some small livestock. The village grazing areas were the most important communal grazing land for those families with small herds of cattle. They derived from these areas not only grazing but also veld products, thatching grass, firewood and water for their livestock; (2) Dry season grazing areas: plains around perennial water sources, swamps, lagoons, lakes and river areas. Before the introduction of fencing and rangeland enclosures, Lake Ngami flood plains and surrounding riverine vegetation have served as dry season grazing reserves. According to information gathered through key informants and through focus group discussions, each herder was expected by the village chief and/or community to take his/her livestock out of these areas immediately after the first rains when water had collected in the sand veld pans; (3) Wet season grazing areas: central to these rangelands were the traditional natural water ponds and pans spreading along vast sands of the dune system in the sand veld areas. These water sources are surrounded by wet season grazing areas.

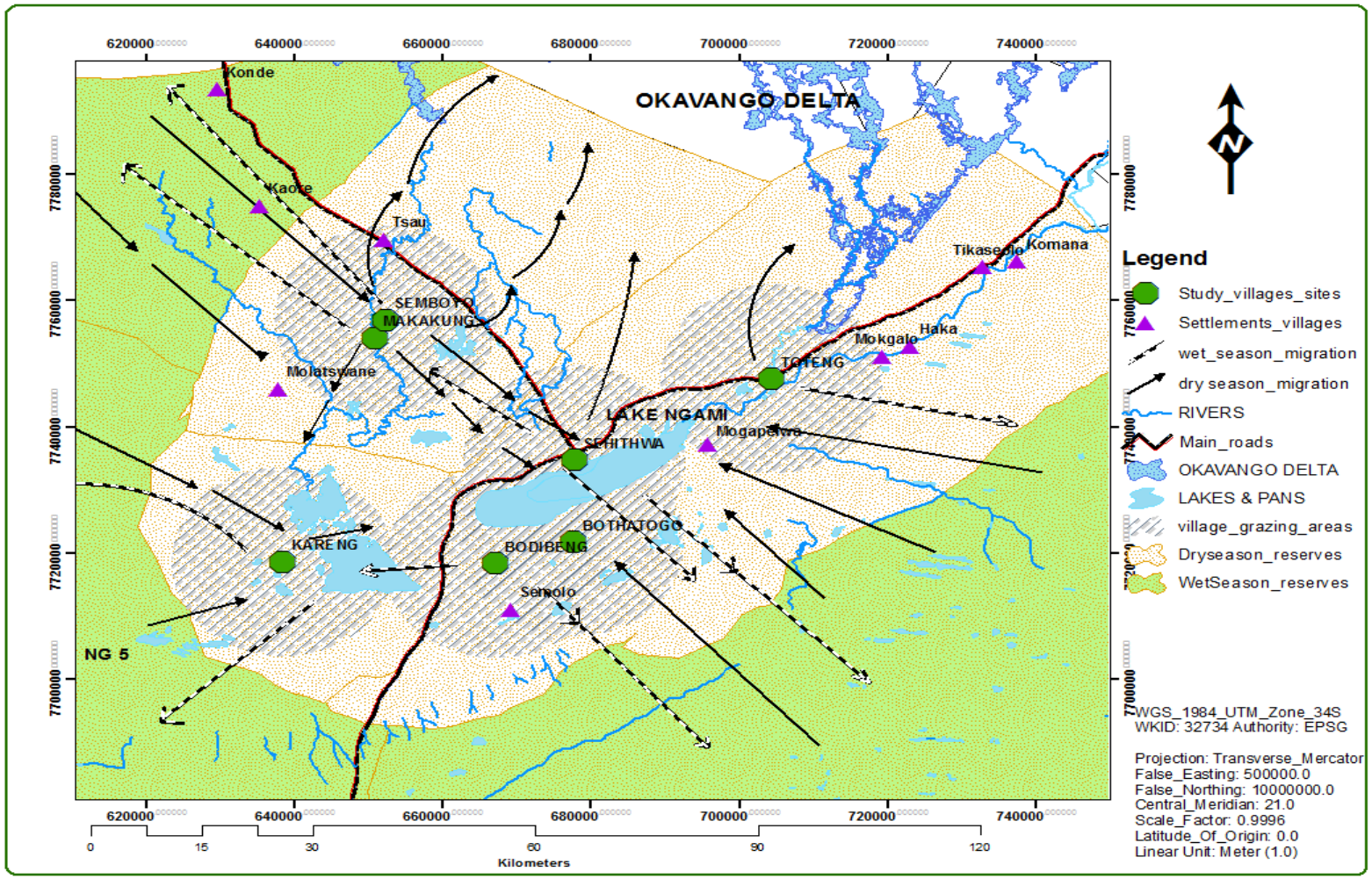

Figure 3: Combined pastoralists' participatory map, showing grazing zones and historical migration patterns before major policy interventions took place.

3.2. Traditional management institutions and access to pasture resources

Information gathered through in-depth interviews and oral narratives reveals that before the rangelands policy interventions, pastoralists' movements were prescribed and regulated through traditional institutional arrangements. Traditional village Chiefs were the custodians of the land and determined rules of access including regulating seasonal livestock movements. Grazing areas were established around seasonal encampments known as cattle posts. Places that contained dry season grazing resources and seasonal water sources were considered critical to the pastoral production system. Clans or kin networks controlled different pans and wells at their cattle posts, including surrounding rangelands. Each of these rangelands was based on some physiographic features and defined genealogically. Rights to a cattle post could be inherited or claimed by virtue of customary use. Rules and regulations that controlled access by non-clan members were through reciprocal access agreements. Pastoralists moved livestock around the three grazing zones in accordance with orally defined demarcations, rules and regulations. Word of mouth was enough, for example, to restrict access to the delta swamps, located to the north of Lake Ngami, whose forage was reserved to be used during periods of severe forage scarcity or as a last resort during drought.

Moreover, risks imposed by environmental conditions such as livestock diseases, livestock predation and recurrent dry spells and sometimes flooding of the Okavango delta, demanded flexibility in pastoralists decision making. Flexible spatial mobility ensured that pastoralists were able to mitigate risks and avert disasters. Pastoralists assert that before the privatisation policies when land was available, they engaged in an adaptive system of livestock herding and management which involved guiding and

controlling livestock movement including herd splitting; dividing livestock into separate herds depending on their age, sex or type for increased niche specialisation. As the chairperson of Kareng Village Famers association argued during key informant interviews, *'…herd splitting resulted in increased livestock niche specialisation, in reduced competition among livestock for the same vegetation species,…in improved livestock watering practices and in the distribution of grazing pressure as each animal was taken to the pasture land which best suits its characteristics…*'

From the early 1960s, some households gained more exclusive use of rangelands by investing in drilling and equipping boreholes. The advent of borehole technology meant that resourceful farmers were able to open up new lands for grazing. Pastoralists sought permissions from their chief to establish cattle posts around their boreholes, which would enable them to have influence over the pasture nearby. Non-borehole owners continued to conduct their seasonal herd movements between perennial water sources including Lake Ngami, riverine floodplains and pans in the sand veld. Some borehole owners also continued the practice of seasonal mobility mainly to alleviate grazing pressures around their boreholes and also to allow underground water to recharge during the wet season. Respondents argued that borehole owners were lucky because privatisation policies, especially the NPAD, later gave them preferential treatment in the ranch allocation process.

3.3. Indigenous grazing system and traditional patterns of seasonal mobility

Pastoralists around Lake Ngami reported during the focus groups that immediately after the first rains, herds moved slowly away from Lake Ngami and surrounding riverine rangelands back to the south. The first rains fall in September/October and

livestock must move to the south to take advantage of renewed pastures and water in the sand veld pans. The move was an attempt to make optimal use of the rain and also lessen pressure on deteriorated dry season pastures. Based on the composition and size of herd owned and available fodder, pastoralists pressed on towards the *Khwebe* hills in the current commercial ranches area. Those with the largest herds made the longest moves while those with fewer cattle moved a shorter distance. In good years, the return might be delayed until late winter (around July or August) because the wells and pans (*macha*) retained water for a longer time. In drought years,for example, during the 1965/1966 and 1982 droughts periods, this return would commence immediately after arable farmers had harvested (around April/May). Once back, the grazing pressure around settlements and water resources increased significantly, so the incentive to delay the return was a positive one. The movement was also vital for small-scale arable farmers who utilised the rivers and floodplains for flood recession arable farming. These fields were not fenced and hence the problem of cattle raiding crops was avoided. Once the harvest was complete and harvests collected, some weaker stock such as lactating cows and calves were returned to feed on crop residues. Pasturing on agricultural fields or village grazing areas was quite brief, lasting for a month and livestock had to move out with the beginning of winter.

Opportunistic movements in response to the highly spatially and temporally variable occurrence of green grass in response to rainfall and fire events were critical. Riverine and floodplain pastures were strictly conserved for use during the dry season or during periods of drought. Pastoralists indicated that permanent grazing in floodplains exposes livestock to parasites such as liver fluke and roundworms which develop rapidly under moist conditions. Owing to this risk, grazing on Okavango Delta system swamps and floodplains was limited to the dry seasons when water levels had

subsided. In extreme situations of drought or abnormal fluctuations in environmental conditions, pastoralists became more mobile and sometimes moved outside the core of their territory, negotiating access with other pastoralists where necessary.

3.4. Spatial comparisons and the impacts of grazing policies

Spatial comparisons of the current situation as mapped by herders' shows that the functional distinction between village grazing areas, dry season grazing areas and wet season grazing areas have been eroded by rangeland policy interventions. Herds are confined around settlements, as commercial ranches have replaced wet season grazing areas to the south of Lake Ngami. Some cattle posts are located only about 2 km from settlements. To the north these rangelands have been bisected by veterinary fences, significantly reducing the area available for communal pastoralism (Figure 4).

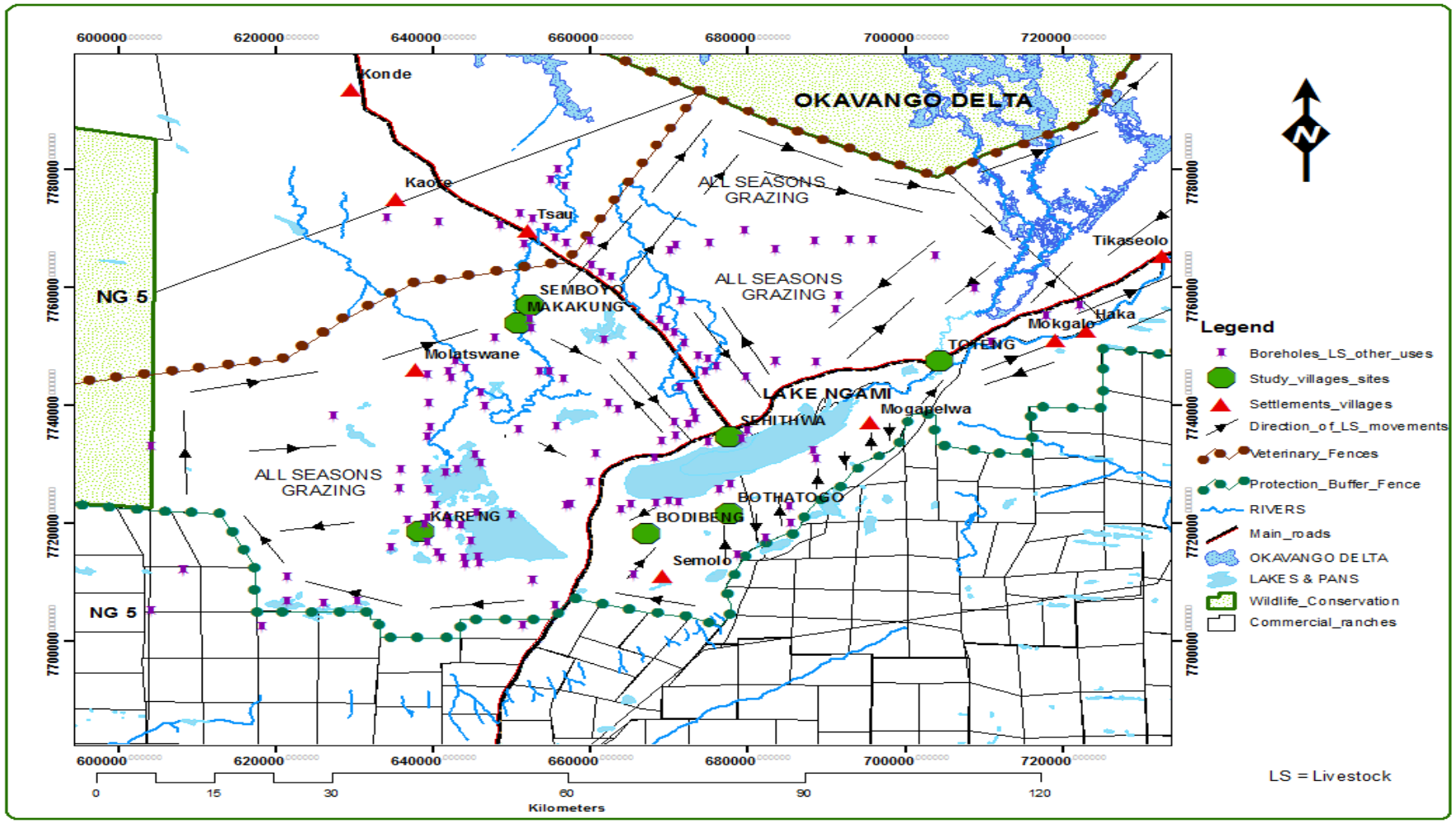

Figure 4: Spatial configuration after the transformations showing all year grazing areas and the directions of livestock movements.

This significant reduction in the amount of communal grazing lands available to pastoralists was not accompanied by a reduction in cattle numbers. Pastoralists argued that cattle numbers continued to increase and are currently very high. This argument is supported by the livestock trend statistics from the Department of Veterinary Services as depicted in figure 5 which indicates a continuing increase in cattle numbers in the communal areas.

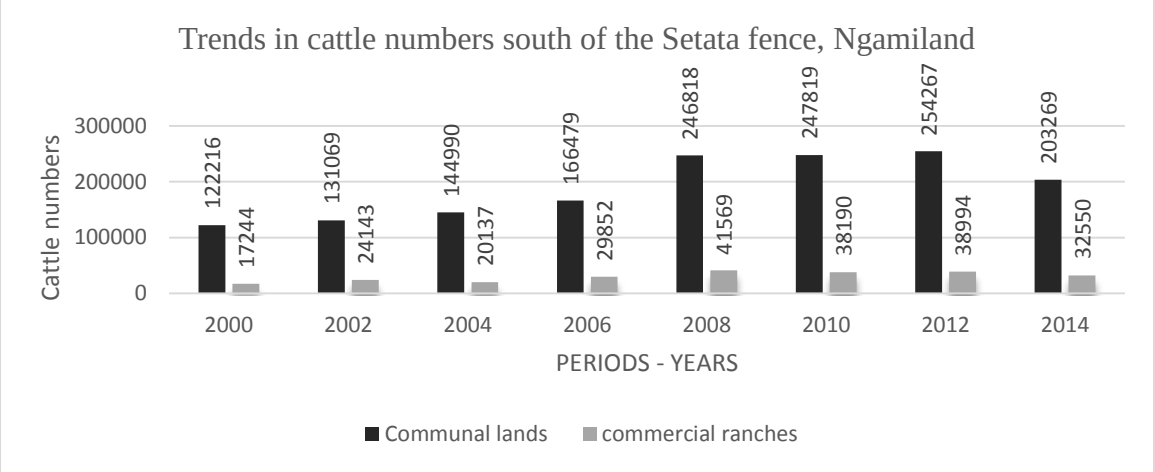

Figure 5: Cattle numbers, 2000 – 2014 Data source: Department of Veterinary Services (DVS)

Table 1: A GIS-estimate of pastoralists' grazing areas before the privatisation policies (square kilometres)

		Grazing zones		
Study villages	***Village grazing areas***	***Dry season grazing areas***	***Wet season grazing areas***	***Total***
Semboyo/Makakung (Setata)	*705*	*2,009*	*2,598*	*5,312*
Kareng (Western Sandveld)	*695*	*850*	*4,586*	*6,133*
Bothatogo/Bodibeng/Toteng/ Sehithwa (lake villages)	*1,863*	*2,942*	*6,131*	*10,935*
Total	***3,263***	***5,801***	***13,315***	***22,380***

As pastoralists' argued, current rangelands are congested, heavily over-utilised and conflicts are prominent. Table 1 provides a GIS-estimated measure of the areas used by pastoralists before land privatisation and subdivision. The current grazing area between the fences (Figure 4) measures 7, 371 km2 as all season grazing areas shared by all villages in the study area, compared to 22,380 km2 of wet, dry and drought season grazing before the fences. Approximately 65% of the communal lands has been lost to privatisation and subdivisions since 1975. This scenario underscores the impacts of rangelands policies on livestock spatial mobility, traditional grazing patterns and access to rangeland resources.

Interviews with key informants focusing on their spatial knowledge revealed that after the introduction of fences and ranches, spatial mobility declined significantly and year-round use of formerly dry season riverine riparian pastures and village grazing areas increased. This has prompted uncontrolled livestock movements, livestock crop damage, stray livestock and increased human-wildlife conflicts, especially with elephants, as migratory corridors have been bisected by fences. *'…we think that when fences were constructed, no due consideration was given to wildlife traditional migratory corridors, fences have diverted wildlife, especially elephants into our cattle posts and arable lands...elephants are everywhere and can no longer follow their traditional routes from the delta to the sand veld…the destructions are so much…'* lamented one elderly pastoralist at Bothatogo village during the key informant interviews. Wildlife opportunities to disperse into the sand veld pastures during the wet season are limited as most have been foreclosed by fences.

Pastoralists also assert that control of livestock diseases is difficult because of congestion in communal areas. Livestock numbers in communal areas continued to escalate and grazing pressures around watering points were reported to be high.

Opportunistic ranchers with access to privatised land continue to keep large numbers of cattle in communal areas. This allows them to sell when opportunities for markets arise on either side of the fence. During periods of drought or prolonged dry seasons, they retreat to their own exclusive private ranches. Ngamiland pastoralists' today struggle to continue a tradition of transhumance or temporary migration that has sustained them for many years as land has been dissected with commercial ranches, veterinary fences and wildlife conservation areas. Livestock movement patterns tend to be chaotic and severely limited. Pastoralists follow individualistic strategies to access grazing and water resources with little regard for the old traditions of consensus. Most reported that it is no longer possible to migrate away from Lake Ngami or the surrounding riverine vegetation during the wet season because there is nowhere to which they can migrate.

3.5. Access to water resources

Competition for water is a major source of land and natural resource use pressure among pastoralists in the study area. Water rights are crucial to the sustainable management of land. Water demand for livestock is ever increasing due to the enclosure of some natural water pans by ranches. Figure 4 indicates some natural water sources that have been either enclosed by commercial ranches or separated by veterinary fences. Pastoralists argued that the decision by the government to allow enclosure of natural water pans by private farms had weakened traditional rangeland management systems, deprived pastoralists of valuable assets and fostered conflict over the remaining water sources, as well as contributing to land degradation caused by livestock congestion around Lake Ngami. During the dry season, the seasonal

rivers dry up. The occurrence of droughts and irregular timing of the rainy season also worsens the situation. Competition over access to water between and within land use systems, especially between livestock and wildlife, is widespread as most of the natural ponds are now enclosed by private farms. Only 30% of the 26 pastoralists interviewed during key informants' interviews, indicated that they own livestock boreholes of their own, the rest depend on natural water sources or are tenants to those with boreholes. Privatisation and subdivision have created uncertainty with regards to access to and control over water resources. Pastoralists argued that the creation of private water points in communal areas was used as a strategy by elites to gain access to privatised communal lands as the NPAD policy later gave preference to those with water points when allocating ranches. Moreover, pastoralists argued that most of the underground water is saline and some borehole owners, including ranchers, continue to use natural water sources, natural ponds, lagoons, rivers and lakes to water their livestock.

3.6. Current land use

The current size of the communal grazing area is much smaller compared to the pre-interventions area. An assessment of land use categories within this area (Figure 4) shows a spatial configuration of cattle posts concentrated around permanent water sources, settlements, and arable fields. The effects of privatisation and subdivision are reflected mostly by the changing patterns of pastoral land use, including the year-round use of critical grazing reserves which were previously used only for a season in a year. Livestock is concentrated near major settlements, roads, rivers and the lake (Figure 6). Herders are now confined to smaller areas with limited access to the

broader range of ecological zones that were traditionally used for managing environmental variability.

Herding practices such as niche specialisation of herds were dismantled as flexible movements were curtailed. *'…Hainaveld formed our grazing reserves and wet seasons retreat…these ranches and fences have displaced us from our traditional grazing land and significantly destructed our traditional land use system…our system of pastoral and land management was neither random or irrational, but deliberate and adapted to the conditions of our environment…now the tiny piece of land we have is congested and overgrazed…',* argued a focus group participant at Sehithwa village. The distinctions between land use systems, cattle posts, arable lands and settlements is unclear. The area between the lake and the ranches was described by pastoralists as a zone of competition and stocking pressure due to the ever increasing number of cattle in the area. Pastoralists displaced by the ranches have been encroaching into this zone. The area is decreasing as ranches are expanding into it, pushing the communal pastoralists further towards the villages. Furthermore, pastoralists reported that they have lost access to their ancestral grazing lands. For indigenous pastoralists, the land and its surrounding environment, provided strong spiritual and cultural values; a source of life and a symbol of respect. Privatisation has resulted in the dismantling of customary boundaries and subdivisions of ancestral lands.

Based on land use concentrations and using ArcGIS proximity and geographic distribution analysis, we utilised land use data (cattle posts and arable lands) obtained from Landsat 8 imagery, and GPS based transect walks to estimate land use pressure zones in the study area. The standard distance, at 25182.25 m from the centre of concentration (Lake Ngami) represent the highest degree of compactness of land use (severe pressure zone). Beyond this distance, the dispersion increases and hence

land use pressure decreases (moderate land use pressure zone). The types of land use pressures and their associated impacts (Table 2) were identified by pastoralists during focus group discussions. Figure 6 identifies land use pressure zones. The concentration of land use activities is around Lake Ngami and the ranches hence these areas suffers the greatest land use and grazing pressure.

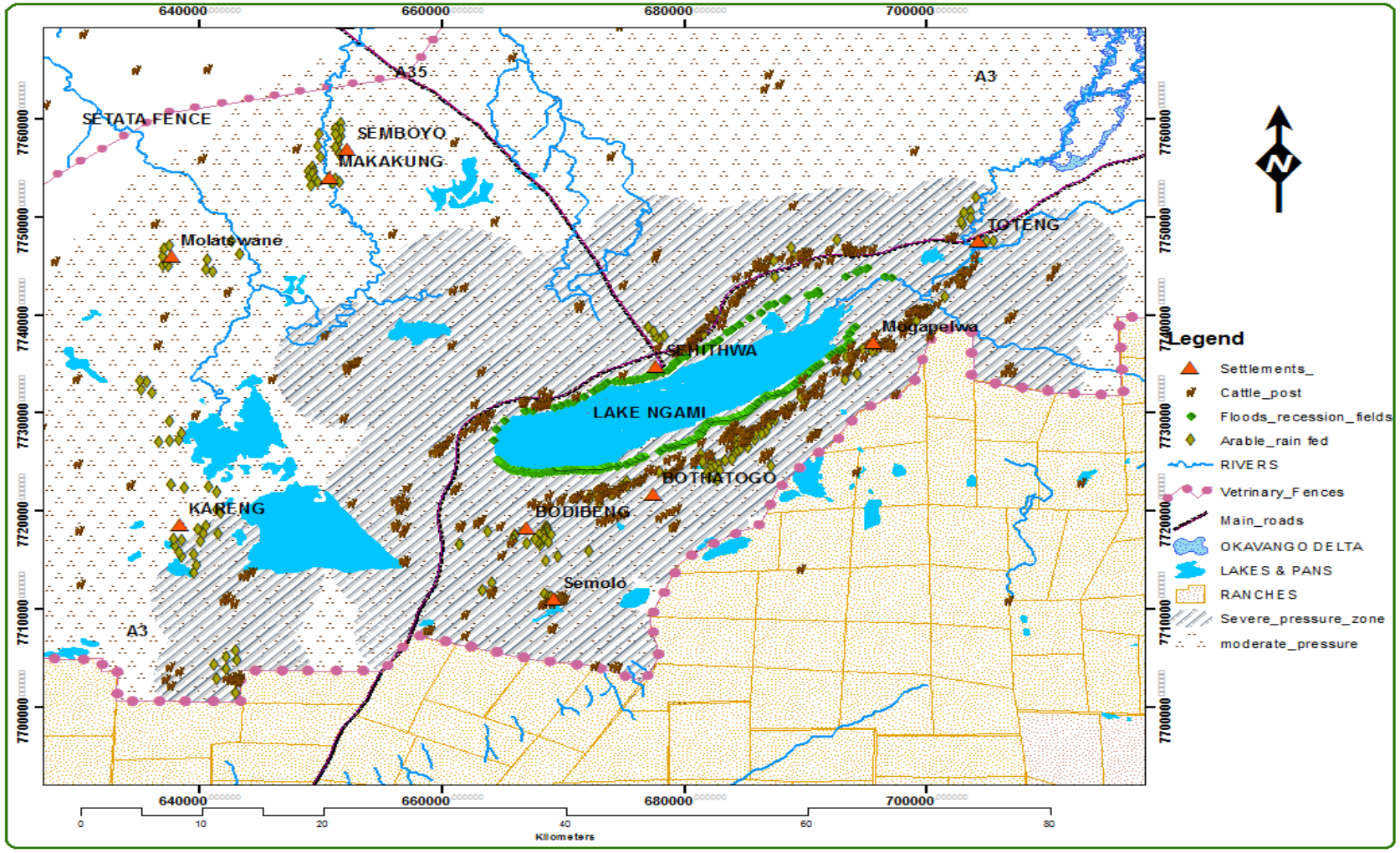

Figure 6: Land use pressure areas (cattle posts concentrations) and other land uses; ranches, arable fields superimposed to identify areas of competing land use using spatial statistics (mean centre and standard distance)

Table 2: Pressures and associated impacts due to fences and growth in livestock numbers in the communal areas

Land use pressure	Associated Impacts
Fences and expansion of ranches– restricted access	Lose of grazing and water resources, blockage of livestock and wildlife migratory corridors, curtailment of seasonal migrations.
Concentration of cattle closer to permanent water sources, e.g. Lake Ngami	Overstocking of floodplains and riparian rangelands, piosphere based rangeland degradation, destruction of ecosystems, difficult to control disease incidences, e.g. Foot and Mouth (FMD).
Land use overlaps; arable land, cattle posts and wildlife	Land use competitions and conflicts; destruction of crops by livestock and wildlife, predation, human elephants conflicts
Dual grazing – opportunistic stocking strategies	Resource use conflicts, overstocking in communal areas land use conflicts and strained local social relations between ranchers and communal area pastoralists
Borehole based livestock expansion in an area with poor groundwater	Borehole drilling along dry river valleys where shallow ground water exists, rapid development of sacrifice and bush encroachment zones

As common pastures are enclosed for private use, natural water ponds and trekking routes are blocked and wildlife migratory corridors are either blocked or diverted. Grazing pressure and conflicts both intensify and communal pastoralists bear the effects of ecosystem deterioration. The research area contains four land use systems. Drawing a transect from the south to the north, land use categories and management regimes range from commercial farming on privately owned ranches (both livestock and game), subsistence agro-pastoralists squeezed in the area between the fences where land use and grazing pressures are intense (settlements, arable and cattle posts), the contested wildlife management area to the south-west (NG5) and a network of veterinary fences followed by a purely commercial wildlife management area and tourism facilities to the north-eastern part where pastoralist production systems are restricted.

4. DISCUSSION

4.1. Indigenous knowledge, rangeland privatisation and spatial mobility

Pastoralists have developed knowledge and skills to cope with environmental variability (Solomon et al., 2007) including comprehensive systems of seasonal migrations and livestock mobility under controlled grazing patterns. The most pertinent challenge faced by pastoralists today is access to sufficient pasture resources and portable water to sustain their livestock through both good and drought years. Pastoralists were particularly wary of problems associated with livestock spatial mobility. Privatisation was supposed to reduce problems of congestion in communal areas, but instead, it has exacerbated the problem of congestion and significantly curtailed livestock mobility. As elsewhere in sub – Saharan Africa, pastoralists continue to suffer extreme marginalisation due to reduced access to pastureland (Lesorogol, 2008, Bogale and Korf, 2007). Researchers have shown how policy interventions in rangelands have ignored traditional pastoral systems, leading to a widespread loss of rangeland productivity and an increase in pastoral poverty (Taylor, 2012, Bassett, 2009, Rohde et al., 2006). In Ngamiland, pastoralists blamed the government policy interventions for the loss of traditional grazing territories, erosion of traditional management institutions' and the overall rangeland degradation in the communal areas.

The findings of this study show that the inhabitants of Ngami area used to follow a traditional transhumant pattern of pastoralism with seasonal movement to and away from Lake Ngami and surrounding Okavango delta floodplains. The enclosure of formerly wet season pastures and water resources by private ranches in the sand veld

and the curtailment of livestock spatial mobility by veterinary cordon fences undermined the livelihoods of local pastoralists. Our findings suggest that the loss of critical wet season grazing reserves was due to failure to recognise the spatial heterogeneity of Ngamiland pastoral landscape, including diversity within traditional pastoralists' management strategies. This scenario is compounded by the dual grazing rights problem in which ranchers continue to use loopholes in policies to graze their livestock in the communal areas (Mulale et al., 2014, Magole, 2009, White, 1992). This was reported to be widespread in Ngamiland. The major impact of subdivisions and privatisation is the constriction of livestock spatial mobility, the destruction of traditional grazing patterns and the fragmentation of ecosystems as wildlife habitats and migratory corridors are bisected. Conflicts about access to resources and human-wildlife conflicts have increased as pastoralists argue that wildlife migratory routes have been diverted by the fences.

4.2. Participatory mapping, PGIS and government planning

The study set out to investigate pastoral land use and livestock spatial mobility within the context of herders' spatial knowledge system using participatory mapping and PGIS. Conventional land administration systems which focus mostly on fixed tenure systems are often not equipped to capture the dynamism inherent in traditional pastoralists' tenures (Bennett et al., 2013), especially in sub – Saharan African rangelands. This process generated unique spatial knowledge in relation to traditional grazing systems, pasture boundaries and the impacts of rangeland policies. It also facilitated a spatially explicit discussion (Talen, 2000), which enabled pastoralists to articulate their viewpoints in a spatially explicit manner. In addition to spatial data,

participatory mapping processes provide non-spatial information such as histories, social relations and patterns (Levine and Feinholz, 2015). By collecting evidence from the field through participatory mapping and GPS based transect walks, overlapping claims to pasture boundaries can be identified and mapped as spatial units, for example, conflict-prone areas or land use pressure zones. Such information can inform planning and/or strategies for resolving land use conflicts in the communal areas.

As it stands, most governments land use classification systems are inherently rigid (Smith, 2003) and fail to incorporate diversity in indigenous pastoral landscapes. Indigenous pastoral lands have mostly been presented as empty spaces (Smith et al., 2012) by some rangeland policies. For example, Botswana's TGLP assumed that there was an abundance of empty lands which could be turned into ranches or even reserved for future use (Magole, 2009, Childers, 1981). However, many such 'unused' lands were actually rangelands that were critically important to pastoralists for managing routine dry spells or drought cycles, as demonstrated in this paper, or used by nomadic hunter-gatherers. Participatory mapping allows for the full conceptualisation of the dryland pastoral landscape, pastoral land use spatial organisation, and the diverse connection between indigenous pastoralists' practices, ecosystems and local boundaries. Such an approach allows cognitive geographic knowledge to be formalised, geo-referenced and placed within the frameworks of geospatial technologies to reveal and improve geographic understanding (Smith et al., 2012) of pastoral landscapes. Smith (2003) notes that, when map making remains only with government officials or bureaucratic elites, they inherently neglect features of the landscape that are important and most relevant to indigenous communities. We agree and argue by extension that analysing pastoral land use through local actors'

spatial knowledge allows resources users to depict not only their grazing space but the interrelationship between resource temporal arrangements and its spatial functionality.

Local pastoral communities reported that it was the first time that they had been involved in a project in which they drew their own maps and delineated boundaries. One of the challenges, however, of using participatory mapping and PGIS is in raising expectations that ultimately their land use challenges will be addressed. Pasture boundaries and alienation of productive grazing lands and encroachment by ranches remains a source of disputes between pastoralists, government officials' and ranchers. Pastoralists strongly felt that the maps produced will help them present their case to the relevant authorities or make their case for land heard. Though the study did not aim at resolving pastoralists' issues and problems, nor advocate for the dismantling of existing private rights, it did offer an alternative way of studying pastoralists' issues through participatory mapping and PGIS to produce useful cartographic information and empirical evidence with regard to problems of privatisation and subdivisions of communal grazing lands. Such an approach is limited in the pastoral research literature. Future policy directions and indeed the ongoing privatisation processes might need to be considered within the context of local spatial narratives, maps and local environmental knowledge to avoid further consequences to the rural poor.

When combined with participatory mapping, the analytical power of GIS offers opportunities to study territorial issues, resolve conflicts, and study and monitor the impacts of land transformations on the pastoral landscape. As a consequence, this research offers possibilities for the use of participatory mapping and GIS-driven methodologies in pastoral management systems and research studies. The empirical evidence and experience, drawn from this research, shows that pastoralists can work

with researchers to transform their cognitive spatial knowledge into forms that can inform policy. The basic spatial relationship between indigenous people and the natural environment in which they make their living is often poorly understood by government planners and/or policy makers (Herlihy, 2003). Yet instead of playing an active role in research agendas, pastoralists are often the subject of research (Vetter, 2005). Their needs priorities, environmental and spatial knowledge are often omitted in policies that directly affect them. Participatory mapping and PGIS then becomes an alternative way of producing environmental and spatial knowledge by decentralising the process (Herlihy and Knapp, 2003) and putting it in the hands of indigenous resource users. This research has documented the spatial extent of livestock mobility and traditional grazing reserve zones, providing a measure of traditional pastoral land use patterns before and after rangeland policies. By creating indigenous spatial maps of pastoralism and making spatial comparisons of the impacts of rangeland policies over time, the study reveals, in a novel way, the spatial impacts of the contested land transformation that have taken place in Ngamiland since 1975.

5. CONCLUSION

This study demonstrates how participatory mapping and GIS can be used to foster better articulation and understanding of pastoralists' tenures and grazing patterns. Pastoralists from all the focus groups lamented the diminishing of communal grazing lands and constriction in livestock spatial mobility as ranches have taken away large tracts of land from communal ownership. Pastoralists argued that animal health and rangeland policies do not recognise their indigenous resources rights, traditional grazing territories and management systems. Efforts to negotiate with authorities have

been vague mainly due to lack of documented spatial information on their grazing territories. Pastoralists saw the value of participatory mapping as a way of gaining empirical evidence and detailed information which they can use to engage relevant government entities or defend their grazing space against expropriation by state or opportunistic elites and also help them manage their resources in a sustainable manner. This study reveals that herders are endowed with a wealth of spatial knowledge about their grazing territories. This knowledge is rarely documented or incorporated in conventional government planning processes. The PGIS approach produces valuable pastoral land use and spatial information vital for the sustainable management of land in the dryland environment where mobility and resource access remains at the core of pastoral sustainability. As communal lands continue to shrink and prospects for sustainable pastoralism becomes more uncertain, future research will need to focus on pastoralists' adaptations within this constrained environment and how pastoralist production systems can be made resilient in the face of continued environmental and policy change.

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7. REFERENCES

ADAM, Y. O., PRETZSCH, J. & DARR, D. 2015. Land use conflicts in central Sudan: Perception and local coping mechanisms. *Land Use Policy,* 42**,** 1-6.

APRU 1976. An Integrated Programme of Beef Cattle and Range Research in Botswana: 1970 – 1976. *Animal Production Research Unit (APRU), Ministry of Agriculture, Gaborone.*

BASSETT, T. J. 2009. Mobile pastoralism on the brink of land privatization in Northern Cote d'Ivoire. *Geoforum,* 40**,** 756-766.

BENJAMINSEN, T. A., HOLDEN, S., LUND, C. & SJAASTAD, E. 2009. Formalisation of land rights: Some empirical evidence from Mali, Niger and South Africa. *Land Use Policy,* 26**,** 28-35.

BENNETT, R., ZEVENBERGEN, J. & LENGOIBONI, M. 2013. The pastoralist's parcel: towards better land tenure recognition and climate change response in Kenya's dry lands. *FIG Working Week 2013, Environment for Sustainability, Abuja, Nigeria*.

BOGALE, A. & KORF, B. 2007. To share or not to share? (Non-)violence, scarcity and resource access in Somali Region, Ethiopia. *Journal of Development Studies,* 43**,** 743-765.

BRIMP 2002. The Biomass Map of Botswana: Growing Season 2000/2001. *Botswana Range Inventory and Monitoring Project (BRIMP), Ministry of Agriculture, Gaborone.*

BURGESS, J. 2004. Country Pasture/Forage Resource Profile. *Ministry of Agriculture, Gaborone.*

CHAN, D. V., HELFRICH, C. A., HURSH, N. C., ROGERS, E. S. & GOPAL, S. 2014. Measuring community integration using Geographic Information Systems (GIS) and participatory mapping for people who were once homeless. *Health & Place,* 27**,** 92-101.

CHANDA, R., TOTOLO, O., MOLEELE, N., SETSHOGO, M. & MOSWEU, S. 2003. Prospects for subsistence livelihood and environmental sustainability along the Kalahari Transect: The case of Matsheng in Botswana's Kalahari rangelands. *Journal of Arid Environments,* 54**,** 425-445.

CHAPIN, M., LAMB, Z. & THRELKELD, B. 2005. Mapping Indigenous Lands. *The Annual Review of Anthropology,* 34**,** 619 - 638.

CHILDERS, G. W. 1981. Western Ngwaketse Remote Area Dwellers: A Land Use and Development Plan for Remote Area Settlements in Southern Botswana. *Government Printers, Botswana*.

CLEAVER, K. M. & DONOVAN, W. G. 1995. Agriculture, poverty, and policy reform in sub-Saharan Africa. *World Bank discussion papers. Africa Technical Department series. Washington, D.C. : The World Bank. ,* WDP 280.

CULLIES, A. & WATSON, T. 2005. Winners and Losers: Privatising the commons in Botswana. *Willprint, Colchester*.

DENZIN, N. & LINCOLN, Y. 2000. *Handbook of Quantitative Research,* London, Sage Publications.

DMS 2013. Ngamiland Rainfall Statistics. *Department of Meteorological Services, Ministry of Environment Wildlife and Tourism, Gaborone, Botswana.*

DOL 2009. Department of Lands (DoL). Ngamiland Integrated Land Use Plan, Final Report, . *Ministry of Lands and Housing, Botswana.*

DOUGILL, A. J., AKANYANG, L., PERKINS, J. S., ECKARDT, F. D., STRINGER, L. C., FAVRETTO, N., ATLHOPHENG, J. & MULALE, K. 2016. Land use, rangeland degradation and ecological changes in the southern Kalahari, Botswana. *African Journal of Ecology,* 54**,** 59-67.

DOUGILL, A. J., THOMAS, D. S. G. & HEATHWAITE, A. L. 1999. Environmental change in the Kalahari: Integrated land degradation studies for nonequilibrium dryland environments. *Annals of the Association of American Geographers,* 89**,** 420-442.

DUNN, C. E. 2007. Participatory GIS - a people's GIS? *Progress in Human Geography,* 31**,** 616 - 637.

ELLIS, J. E. 1995. Climate variability and complex system dynamics: implications for pastoral development. *In: Scoones, I. (ed.), Living with Uncertainty: New directions in pastoral development in Africa, Intermediate Technology Publications, Exeter***,** 37 - 46.

GALATY, J. G. 2013. Land grabbing in the Eastern African rangelands. *In: Catley, A., Lind., J., and Scoones, I. (Eds). Pastoralism and Development in Africa: Dynamic Change at the Margins, Pathways to sustainability, Routlege***,** 143 - 153.

HARDIN, G. 1968. The tragedy of the commons. *Science,* 162**,** 1243 - 8.

HAY, I. 2010. *Qualitative Research Methods in Human Geography,* Canada, Oxford University Press.

HERLIHY, P. H. 2003. Participatory research mapping of indigenous lands in Darien, Panama. *Human Organization,* 62**,** 315-331.

HERLIHY, P. H. & KNAPP, G. 2003. Maps of, by, and for the peoples of Latin America. *Human Organization,* 62**,** 303-314.

HO, P. 2014. The 'credibility thesis' and its application to property rights: (In)Secure land tenure, conflict and social welfare in China. *Land Use Policy,* 40**,** 13-27.

HOMANN, S., RISCHKOWSKY, B. & STEINBACH, J. 2008. The effect of development interventions on the use of indigenous range management strategies in the Borana Lowlands in Ethiopia. *Land Degradation & Development,* 19**,** 368-387.

KAKINUMA, K., OKAYASU, T., JAMSRAN, U., OKURO, T. & TAKEUCHI, K. 2014. Herding strategies during a drought vary at multiple scales in Mongolian rangeland. *Journal of Arid Environments,* 109**,** 88-91.

KAYE-ZWIEBEL, E. & KING, E. 2014. Kenyan pastoralist societies in transition: varying perceptions of the value of ecosystem services. *Ecology and Society,* 19.

LEBERT, T. & ROHDE, R. 2007. Land reform and the new elite: Exclusion of the poor from communal land in Namaqualand, South Africa. *Journal of Arid Environments,* 70**,** 818-833.

LENGOIBONI, M., BREGT, A. K. & VAN DER MOLEN, P. 2010. Pastoralism within land administration in Kenya-The missing link. *Land Use Policy,* 27**,** 579-588.

LESOROGOL, C. K. 2008. Land privatization and pastoralist well-being in Kenya. *Development and Change,* 39**,** 309-331.

LEVINE, A. S. & FEINHOLZ, C. L. 2015. Participatory GIS to inform coral reef ecosystem management: Mapping human coastal and ocean uses in Hawaii. *Applied Geography,* 59**,** 60-69.

MAGOLE, L. 2009. The 'shrinking commons' in the Lake Ngami grasslands, Botswana: the impact of national rangeland policy. *Development Southern Africa,* 26**,** 611-626.

MBAIWA, J. E., NGWENYA, B. N. & SETHORA, M. 2008. Ethnicity and Utilization of Natural Resources in the Okavango Delta, Botswana: A Historical Perspective of Conflict and Collaboration. *In:* AHMED, A. (ed.) *Managing Science and Technology for a Sustainable Future: Wasd 2008 Conference Proceedings.* Brighton: World Assoc Sustainable Development-Wasd, Spru-Science & Technol Policy Res.

MCCALL, M. K. & DUNN, C. E. 2012. Geo-information tools for participatory spatial planning: Fulfilling the criteria for 'good' governance? *Geoforum,* 43**,** 81-94.

MORITZ, M., LARISA CATHERINE, B., DRENT, A., KARI, S., MOUHAMAN, A. & SCHOLTE, P. 2013. Rangeland governance in an open system: Protecting transhumance corridors in the Far North Province of Cameroon. *Pastoralism,* 3**,** 1-10.

MULALE, K., CHANDA, R., PERKINS, J. S., MAGOLE, L., SEBEGO, R. J., ATLHOPHENG, J. R., MPHINYANE, W. & REED, M. S. 2014. Formal institutions and their role in promoting sustainable land management in Boteti, Botswana. *Land Degradation & Development,* 25**,** 80-91.

MWANGI, E. 2007. Subdividing the commons: Distributional conflict in the transition from collective to individual property rights in Kenya's Maasailand. *World Development,* 35**,** 815-834.

NEITSCHMAN, B. 1995. Defending the Miskito Reefs with maps and GPS. *Cultural Survival Quarterly,* 18**,** 34 - 83.

NOTENBAERT, A., DAVIES, J., DE LEEUW, J., SAID, M., HERRERO, M., MANZANO, P., WAITHAKA, M., ABOUD, A. & OMONDI, S. 2012. Policies in support of pastoralism and biodiversity in the heterogeneous drylands of East Africa. *Pastoralism,* 2**,** 1-17.

OBA, G. 2013. The sustainability of pastoral production in Africa. *In: Catley, A., Lind., J., and Scoones, I. (Eds). Pastoralism and Development in Africa: Dynamic Change at the Margins, Pathways to sustainability, Routlege***,** 29-36.

PETERS, P. E. 1994. *Dividing the commons: politics, policy, and culture in Botswana,* Charlottesville, University Press of Virginia.

ROB 1975. Republic of Botswana, National Policy on Tribal Grazing Land: Government Paper No. 2 of 1975. *Government Printers, Gaborone, Botswana*.

ROB 1991. Republic of Botswana, National Policy on Agricultural Development (NPAD). *Government Printers, Gaborone, Botswana*.

ROHDE, R. F., MOLEELE, N. M., MPHALE, M., ALLSOPP, N., CHANDA, R., HOFFMAN, M. T., MAGOLE, L. & YOUNG, E. 2006. Dynamics of grazing policy and practice: environmental and social impacts in three communal areas of southern Africa. *Environmental Science & Policy,* 9**,** 302-316.

SCOTT, L. M. & JANIKAS, M. V. 2010. Spatial Statiscs in ArcGIS. *In Fischer, M. M and Getis, A (Eds), Handbook of Applied Spatial Analysis: Software Tools, Methods and Applications*.

SMITH, D. A. 2003. Participatory mapping of community lands and hunting yields among the Bugle of western Panama. *Human Organization,* 62**,** 332-343.

SMITH, D. A., HERLIHY, P. H., VIERA, A. R., KELLY, J. H., HILBURN, A. M., ROBLEDO, M. A. & DOBSON, J. E. 2012. Using Participatory Research Mapping and GIS to Explore Local Geographic Knowledge of Indigenous Landscapes in Mexico. *Focus on Geography,* 55**,** 119-124.

SOLOMON, T. B., SNYMAN, H. A. & SMIT, G. N. 2007. Cattle-rangeland management practices and perceptions of pastoralists towards rangeland degradation in the Borana zone of southern Ethiopia. *Journal of Environmental Management,* 82**,** 481-494.

SPEELMAN, E. N., GROOT, J. C. J., GARCIA-BARRIOS, L. E., KOK, K., VAN KEULEN, H. & TITTONELL, P. 2014. From coping to adaptation to economic and institutional change - Trajectories of change in land-use management and social organization in a Biosphere Reserve community, Mexico. *Land Use Policy,* 41**,** 31-44.

TACHE, B. 2013. Rangeland enclosures in Southern Oromia, Ethiopia: an innovative response or the erosion of common property resources? *In: Catley, A., Lind., J., and Scoones, I. (Eds). Pastoralism and Development in Africa: Dynamic Change at the Margins, Pathways to sustainability, Routlege***,** 37 - 46.

TALEN, E. 2000. Bottom-up GIS - A new tool for individual and group expression in participatory planning. *Journal of the American Planning Association,* 66**,** 279-294.

TAYLOR, J. 2012. Constraints of grassland science, pastoral management and policy in Northern China: Anthropological perspectives on degradational narratives. *International Journal of Development Issues,* 11**,** 208-226.

TONGCO, M. D. C. 2007. Purposive Sampling as a tool for Informant Selection: Research Methods. *Ethnobotany Research and Application: A journal of Plants, People and Applied Research.,* 5.

TOULMIN, C. 2009. Securing land and property rights in sub-Saharan Africa: The role of local institutions. *Land Use Policy,* 26**,** 10-19.

TSEGAYE, D., VEDELD, P. & MOE, S. R. 2013. Pastoralists and livelihoods: A case study from northern Afar, Ethiopia. *Journal of Arid Environments,* 91**,** 138-146.

TURNER, M. D., MCPEAK, J. G. & AYANTUNDE, A. 2014. The Role of Livestock Mobility in the Livelihood Strategies of Rural Peoples in Semi-Arid West Africa. *Human Ecology,* 42**,** 231-247.

VETTER, S. 2005. Rangelands at equilibrium and non-equilibrium: recent developments in the debate. *Journal of Arid Environments,* 62**,** 321-341.

WHITE, R. 1992. *Livestock Development and Pastoral Production on Communal Rangeland in Botswana: Case study for Workshop: New directions in African Range Management Policy, Matopos, Bulawayo, Zimbabwe,* London, UK, Commonwealth Secretariat.