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Using Participatory Mapping and a Participatory Geographic Information System in Pastoral Land Use Investigation: Impacts of Rangeland Policy in Botswana

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Abstract

Since the 1980s, the spatial extent of communal grazing lands in Botswana has been diminishing due to rangeland privatisation and fencing associated with 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. Achieving success in pastoral development research requires a sound understanding of traditional pastoralists' information systems, including the nature of local spatial knowledge. This study explores local spatial knowledge through participatory mapping and a Participatory Geographic Information System to understand and analyse pastoralists' grazing patterns, spatial mobility and the impacts of subdivisions and privatisation policies in Botswana's Ngamiland rangelands. The study uses focus group discussions, historical analysis through key informant interviews, and participatory mapping exercises along with community guided transect walks. The resulting maps provide insights into the traditional tenure patterns of land use and the impacts of rangeland policy on traditional livestock spatial mobility and access to grazing lands. Privatisation and rangeland enclosures have resulted in the restricted movement of livestock and overstocking of floodplains and riparian rangelands, with some natural water pans becoming inaccessible to local communities. We conclude that the integration of local spatial knowledge can be used to foster better articulation and understanding of pastoralists' tenures, which are often lacking in communal land administration systems. Such integrated analysis can contribute to sustainable pastoral land management policy toolkits in semi-arid rangeland environments and enable better land tenure and management decision making for sustainable land management.

Keywords: Communal grazing lands; Pastoralism; Local spatial knowledge; Privatisation; Sustainable Land Management; Okavango Delta

1. INTRODUCTION

Policies and regulations that govern communal grazing lands have important implications for pastoral livelihoods and traditional pastoralism characterised by flexible herd mobility

(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 rapid tenure transformations (Toulmin, 2009). The need to establish private and secure property rights, avert land degradation, and to modernise and commercialise agricultural production has been used to justify numerous land privatisation programmes undertaken through bilateral and multilateral aid agencies (Peters, 2009). The form and content of these rangeland management policies is a result of the modernisation process based on a model of development established in developed countries (Rohde et al., 2006). Enclosure and privatisation of the commons, including a shift from traditional institutions of land management to modern ones, was the policy recommendation to emerge from this modernisation process (Rohde et al., 2006). Pastoralism became a major target of the modernisation model and its subsequent policies (Cleaver and Donovan, 1996).

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). Pastoral land tenure needs secure land use rights that accommodate flexibility in resource access (Fernandez-Gimenez, 2002). The rationale for traditional pastoralism of herd mobility and flexibility has been 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 regimes (Dougill et al., 2016, Kakinuma et al., 2014, Dougill et al., 1999). The survival of herds depends on the pastoralists' ability to respond to variability or uncertainty and hence move to better areas with available fodder (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). For example, in Kenya the need for more spatially extensive rangelands has led some Maasai pastoralists to recombine some private parcels of land to improve mobility strategies (Coleman and Mwangi, 2015).

Pastoral societies are also characterised by a high dependency on local knowledge (Adriansen and Nielsen, 2002). 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). However, changes in statutory land tenure systems through privatisation have interrupted pastoralists' capacity to utilise customary land

rights, including traditional mobility strategies, to cope with eventualities such as drought and disease incidences (Kaye-Zwiebel and King, 2014, Lengoiboni et al., 2010). Most rangeland privatisation policies have not yet yielded the intended benefits (Homewood, 2004). Where land degradation existed it has not been halted (Dougill et al., 2016) and traditional livestock management institutions have been disoriented, undermining traditional livelihoods and rangeland management systems (Peters, 1994).

In Botswana, the policy arrangement that has most significantly impacted communal rangelands is the TGLP of 1975 (Magole, 2009, White, 1992, Childers, 1981). TGLP allowed for the fencing of communal grazing lands for commercial ranches (Adams, 2013). Claims related to the overstocking and degradation of communal grazing lands, including the tragedy of the commons theory (Hardin, 1968), were used to structure and justify policy objectives (Rohde et al., 2006, Cullies and Watson, 2005). The assumption was that the effect of unregulated communal grazing coupled with perceived increases in livestock numbers was responsible for rangeland degradation and that the consequences would become severe (RoB, 1975). Livestock needed to be regulated based on 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). TGLP assumed that there was ample unoccupied land available for privatisation (RoB, 1975). However, implementation was far more difficult than anticipated (Peters, 1994). Many parts of the country that had been assumed to be unoccupied contained substantial numbers of people, some of whom were not cattle herders, such as hunter gatherers (Childers, 1981). Despite these shortcomings, TGLP implementation continued and by 2009 a total of 342 ranches, each measuring approximately 6400 hectares, had been allocated (Mathuba, 2009). The TGLP objectives were expanded and continued by the National Policy on Agricultural Development (NPAD) (RoB, 1991). NPAD targeted the land around communal grazing areas or cattle posts[1] owned by individuals or syndicates (Cullies and Watson, 2005). An additional 552 ranches, each measuring approximately 3600 hectares, were demarcated and allocated under NPAD by 2009 (Mathuba, 2009).

[1] Cattle post is a traditional Tswana livestock management system that involves routine herding confined to kraaling of animals around a water point at dusk and their subsequent release in the morning (Perkins, 1996).

Local communities do not have much say in the ranch allocation process, as it is controlled by the Land Boards and Ministry of Agriculture (Adams, 2013). The allocation process gives those who previously had only de facto rights to grazing around their boreholes exclusive rights to previously communal grazing lands (RoB, 1991). The large costs of drilling and equipping a borehole ensures that owning a borehole remains a privilege of the wealthy, hence most beneficiaries belong to the wealthier echelons of society (Magole, 2009, Perkins, 1996). In a few instances, some poor pastoralists were incorporated into syndicate ranches and granted water and pastures as hirers who paid fees (Peters, 1994). Today, communal pastoralists find themselves surrounded by private ranches and disease control fences which bisect rangelands and separate communal pastoralists from critical grazing resources.

To date, few studies have proposed integration of pastoralists' spatial knowledge, spatial comparisons and/or participatory mapping approaches and a Participatory Geographic Information System (PGIS) to analyse pastoral management systems and the impacts of such transformations as described above. Studies have emphasised the overarching need to generate spatial landscape knowledge regarding pastoralists' tenures and land use in order to develop the capacity of local communities to help governments to reconcile pastoral tenure conflicts and manage resources in dryland areas (Turner et al., 2014, Bennett et al., 2013, Lengoiboni et al., 2010). This study draws on participatory research methods and geospatial technology to explore local spatial knowledge to understand traditional pastoralists' spatial mobility and the impacts of subdivisions and privatisation policies in Botswana's Ngamiland district. Local spatial knowledge is the unique knowledge held by local communities, acquired through practical experience and developed around specific geographic areas (McCall and Dunn, 2012). This study provides important spatial information based on local pastoralists' knowledge that could potentially be used to inform planning. This approach emphasises the involvement of local communities in producing distinctive spatial knowledge of their communities (Smith et al., 2012, Dunn, 2007).

The aim of this study is to explore local 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, past patterns of transhumance, and regulatory mechanisms for accessing grazing lands from before land tenure transformation to the current situation in Ngamiland District, Botswana; and (2) determine current land use patterns and the spatial impacts of rangeland policies on access to grazing and water resources based on respondents' spatial knowledge.

2. MATERIALS AND METHODS

Participatory research methods were used to collect primary data in seven study villages between April and August 2015. Study sites were selected based on proximity to ranches and/or veterinary cordon fences 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, located 42 km southwest of Lake Ngami, and Semboyo/Makakung, located 34 km northwest of Lake Ngami and adjacent to the Setata veterinary fence (Setata villages) (see Figure 1).

2.1. Study area

The study area is located on the southern fringe of the Okavango Delta (Figure 1). Ngamiland was chosen because the number of ranches (approximately 200) demarcated in the district (both through TGLP and NPAD) makes it relevant to the problem being investigated. In addition, the Okavango Delta and the surrounding rangelands are host to a large diversity of natural resources, including wildlife, diverse vegetation and water resources. Land fragmentation due to veterinary cordon fences and protection areas to separate wildlife and livestock is prominent. Wildlife management areas (WMAs) were established based on TGLP's recommendation in the early 1980s (DoL, 2009). The District is further divided into Controlled Hunting Areas (CHAs) for utilisation under the Community-Based Natural Resource Management (CBNRM) programme. Veterinary fences have been created across the district to separate livestock from wild animals, particularly buffaloes which are known carriers of Foot and Mouth Disease (FMD) (DoL, 2009). Field data collection was conducted around Lake Ngami and villages south of the Setata veterinary cordon fence, where the primary livelihood activity is subsistence

pastoralism. The following ethnic groups inhabit the study area: San groups (Basarwa), BaYeyi, Ovaherero, Ovambanderu, Batawana and Bakgalagadi. However, the dominant ethnic groups are the Ovambanderu and Ovaherero (DoL, 2009). The Ovaherero and Ovambanderu are pastoralists who rarely engage in arable agriculture (Tlou, 1985). The climate is semi-arid with distinct hot, wet summers, and cold dry winters. Average annual rainfall ranges between 450 and 550 mm (DMS, 2013). The distribution of rainfall over space and time is highly variable and is the determining factor in grazing distribution (DoL, 2009). Selection and use of natural resources as well as disease pandemics (both human and livestock) have influenced settlements and migration patterns (including configuration of kinship networks) of different ethnic groups around the Okavango Delta (Mbaiwa et al., 2008). Settlements have been largely confined to the margins of the permanent swamps. The sandveld area where the privatised ranches have been demarcated, known as Hainaveld, is located to the south of Lake Ngami.

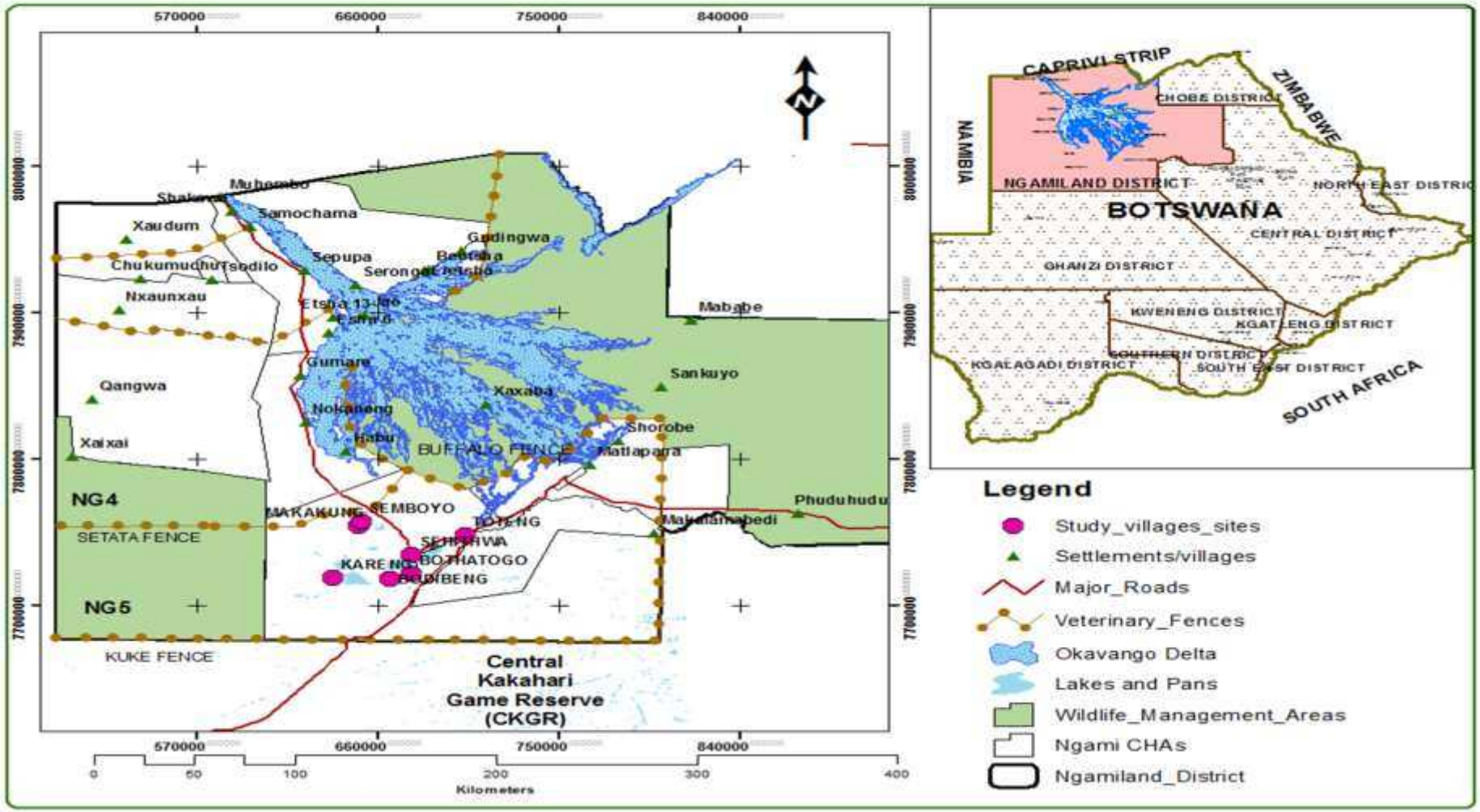

Figure 1: Ngamiland study area, its land uses and study sites. Source: Authors

2.2. Focus group discussions

A total of nine focus group discussions were conducted. One focus group was held in each study village (n = 7), with between 8 and 14 participants in each meeting. These discussions targeted stakeholders and groups in the community, particularly pastoralists with experience in communal areas and members of the farmers' committees[2]. Two additional focus groups targeted only women (a mix of female agro-pastoralists selected from the lake villages, 14 participants) and youth groups (youths engaged in pastoral farming and those that were active in community projects, selected across the study villages, 14 participants) to incorporate divergent views. This approach also helped avoid situations in which influential male members of a group dictate the mapping and discussion process. Farmers' committees, village leadership and village development committees were used to solicit names of participants for focus groups.

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 introduction of fences in the early 1980s, 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 about the names of places and landscape features. A total of 7 transect walks were carried out and the number of volunteers were as follows: Semboyo (n = 4), Makakung (n = 6), Bodibeng (n = 2), Bothatogo (n = 6) Toteng (n = 3), Sehithwa (n = 4), Kareng (n = 4). All discussions were conducted in the Setswana language and tape-recorded.

2.3. Participatory Mapping and PGIS

[2] Farmers committees are community-level lobbying structures representing arable farmers and pastoralists or agro-pastoralists. They argue for the safeguards of pastoralists' land rights and access to water resources and markets. They are also responsible for farmer/pastoralist education and are community liaisons with government departments (DoL, 2009).

Using a cognitive mapping process (Chan et al., 2014), we utilised sketch maps drawn by respondents during the focus groups to determine grazing areas and the spatial extent and patterns of seasonal livestock mobility before and after fences. Participatory mapping can form an important aspect of generating local spatial knowledge (Chapin et al., 2005, Neitschman, 1995), since it allows resource users to convey not only positions of activities but also background details concerning the locations and drivers of land use activities (Levine and Feinholz, 2015). The process involves using maps as tools to acquire indigenous knowledge and portraying this in a spatial way using GIS (Dunn, 2007, Talen, 2000). Pastoralists' maps can be incorporated into the government cadastral classification to improve awareness of pastoralists' customary tenures, thus protecting indigenous grazing land 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 Botswana's Department of Surveys and Mapping in the form of processed Landsat 8 imagery data for 2013 (dry season; June and August) and 2014 (wet season; December and February). The classification was achieved using ArcGIS 'cluster unsupervised classification' tool, in which pixels are grouped using reflectance properties. Accuracy was improved by combining summer and winter data rather than performing single data analyses. The map recorded the following land cover categories: savanna woodland, open low shrubland, swamp vegetation (aquatic herbaceous), natural bare ground or degraded land, natural waterbodies such as pans or ponds, hills and rivers. To validate the land cover map, ground truthing was carried out during two weeks of extensive field surveys in June 2016 (dry season). The field surveys covered most of the accessible areas and landmark features such as natural water bodies or pans, rivers, hills, 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 was obtained from various government departments including the 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, the Tawana Land Board's map showed general land uses while the Ministry of Agriculture had

a more detailed map of agricultural land uses. The land cover map was geo-referenced and then overlaid with land use data. This was done to allow land use features such as roads, settlements and boreholes to appear on the land cover map, so that participants could identify and sketch their grazing spaces around these features. The principal land features on the map that respondents could identify were the Okavango delta, swamp areas, hills, Lake Ngami, roads, rivers, pans, pastoralists' settlements and fences. Borehole data obtained from the Tawana Land Board was also used to help focus group participants identify specific grazing lands and cattle posts. Borehole numbers were shown on the map and attribute data about the boreholes, such as names of owners, were printed on a separate page.

Mapping sessions were conducted with each focus group. At the beginning, participants were asked to identify their settlements and prominent landscape features and to locate their grazing areas or cattle posts. Second, participants were asked to delineate their historical pasture boundaries before the current fences, identifying them according to seasons. This was done on the land cover map provided. 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 land cover map showing the fences and ranches, participants were asked to identify and sketch their contemporary grazing spaces, including the general patterns of livestock movement among all pastoralists in the area (wet season/dry season alternation). The placement of a boundary or migratory movement patterns was achieved through consensus among group members. 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 through a series of key informant interviews as well as visits to cattle posts and conflict-prone zones. The selection of key informants was based on purposive/judgemental sampling (Tongco, 2007). Members of farmers' committees, village development committees and pastoralists in cattle posts were consulted to provide an initial list of potential respondents. Subsequent informants were identified using a snowballing technique (Speelman et al., 2014, Denzin and Lincoln, 2000). Participants were asked if they knew of others who met the selection criteria and could potentially participate in the interviews. A total of 26 informants were interviewed across the study area.

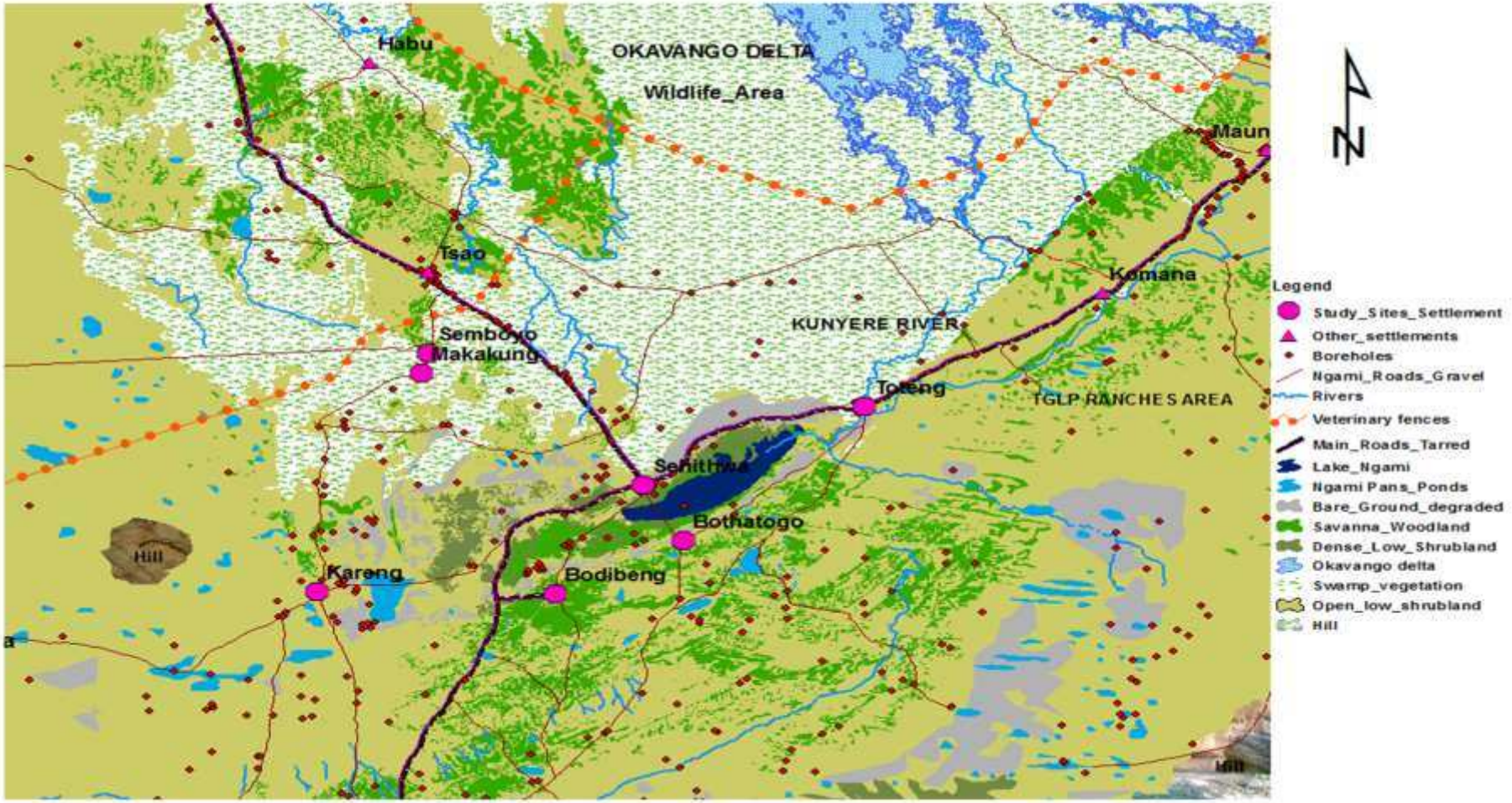

Figure 2: Land cover base Map Source: Authors Data Source: Landsat 8 satellite imagery, Department of Surveys and Mapping, Tawana Land Board

2.4. Data analysis

Maps made by local respondents were scanned and converted to digital versions using ArcGIS software. 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 delineating the full extent of boundaries identified by participants, or participants' impressions of livestock movement patterns before and after the barrier fences. Maps from different villages were overlaid to produce a consolidated map. The aim of the mapping exercise was to provide a landscape-scale picture of the pastoral production system in terms of time and space based on 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, using mean centre and standard distance tools in ArcGIS (Scott and Janikas, 2010). First, we identified the mean centre (the centre of concentration) for the land use features (cattle posts and arable lands or gardens). Standard Distance was then used to measure the degree to which these features are concentrated or dispersed around the mean centre, giving a spatial representation 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) identifying major themes emanating from the discussions (ii) assigning codes to major themes (iii) classifying responses under the identified themes (iv) writing the research narratives and discussions (Adam et al., 2015).

3. RESULTS

This section presents the results of the study based on the study objectives. It examines traditional pastoral systems and grazing zones before land tenure transformations, and makes spatial comparisons of past and present pastoral land use**.** From this information, the spatial impacts of land transformations were analysed.

3.1. Grazing zones before land use and tenure transformation

Information gathered through focus groups and in-depth interviews reveals that before the rangeland policy interventions, pastoralists' movements were prescribed and regulated through traditional institutional arrangements. Traditional village chiefs determined rules of access including regulating seasonal livestock movements. 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 and the surrounding rangelands. Each of these rangelands were delineated based on physiographic features and were defined genealogically.

Before the current land tenure and land use transformations, respondents identified three distinct grazing zones in the extensive indigenous grazing lands (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 key 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 which formed a radius of approximately 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 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, which include plains around perennial water sources, swamps, lagoons, lakes and river areas. Before the introduction of fencing and rangeland enclosures, the Lake Ngami flood plains and surrounding riverine vegetation served as dry season grazing reserves. According to information gathered from key informants and 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.

During focus groups, respondents around Lake Ngami reported that immediately after the first rains, herds moved slowly away from Lake Ngami and surrounding riverine rangelands back to the south (wet season grazing areas). 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 lessen pressure on deteriorated dry season pastures. Based on the composition and size of herds and available fodder, pastoralists pressed on towards the Khwebe hills in the current commercial ranch areas. Those with the largest herds made the longest moves while those with fewer cattle moved a shorter distance. In good years, the return was delayed until late winter (around July or August) because the wells and pans retained water for a longer time. In drought years, such as the 1965/1966 and 1982 droughts periods, this return would commence immediately after arable farmers had harvested (around April/May). Once back in the dry season grazing areas, 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. Livestock had to move 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 periods of drought. Moreover, risks imposed by environmental conditions such as livestock disease, livestock predation and sometimes flooding of the Okavango delta demanded flexibility in pastoralists' decision-making. Permanent grazing in floodplains exposes livestock to parasites such as liver fluke and roundworms, which develop rapidly under moist conditions. Because of this risk, grazing on Okavango Delta system swamps and floodplains was limited to the dry seasons when water levels had subsided. Flexible spatial mobility ensured that pastoralists were able to mitigate risks and avert disasters. Respondents assert that when land was available before the privatisation policies, they engaged in an adaptive system of livestock herding and management which involved guiding and controlling livestock movement with techniques including herd splitting, in which livestock are divided into separate herds depending on their age, sex or type

for increased niche specialisation. *'…herd splitting resulted 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…*' (Interview data, pastoralist, Kareng, 2015).

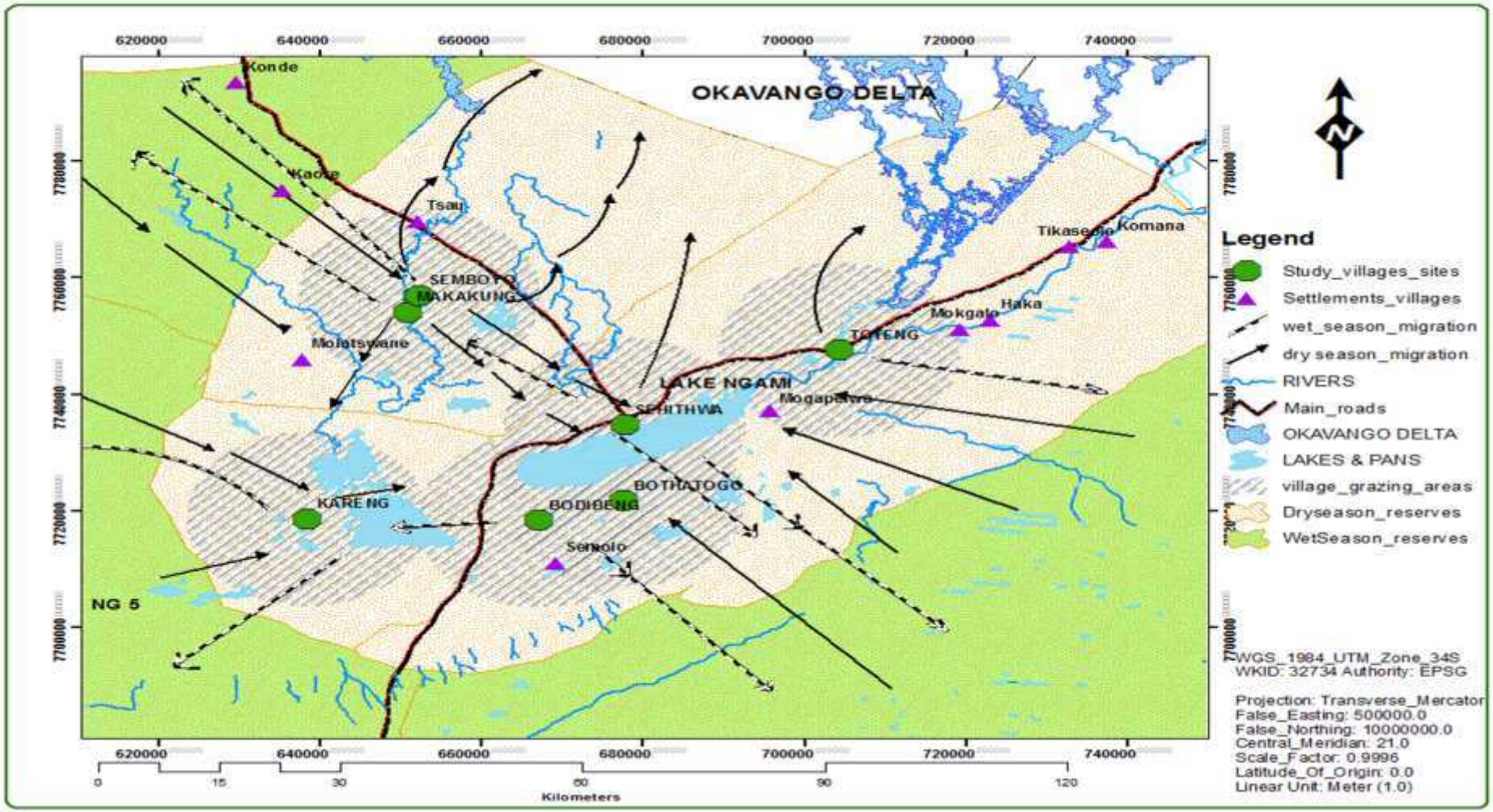

Figure 3: Combined respondents' participatory map, showing grazing zones and historical migration patterns before major policy interventions.

3.2. Spatial comparisons and the impacts of grazing policies

Spatial comparisons of the current situation show that the functional distinction between village grazing areas, dry season grazing areas, and wet season grazing areas have been eroded by rangeland policy interventions. Figure 4 shows the spatial configuration of land use and the land available for communal grazing after land tenure transformation. Herds are confined around settlements, with the areas between the ranches and veterinary fences serving as all-season grazing areas. Commercial ranches have replaced wet season grazing areas to the south of Lake Ngami. To the north, these rangelands have been bisected by veterinary fences. This has significantly reduced the area available for communal pastoralism.

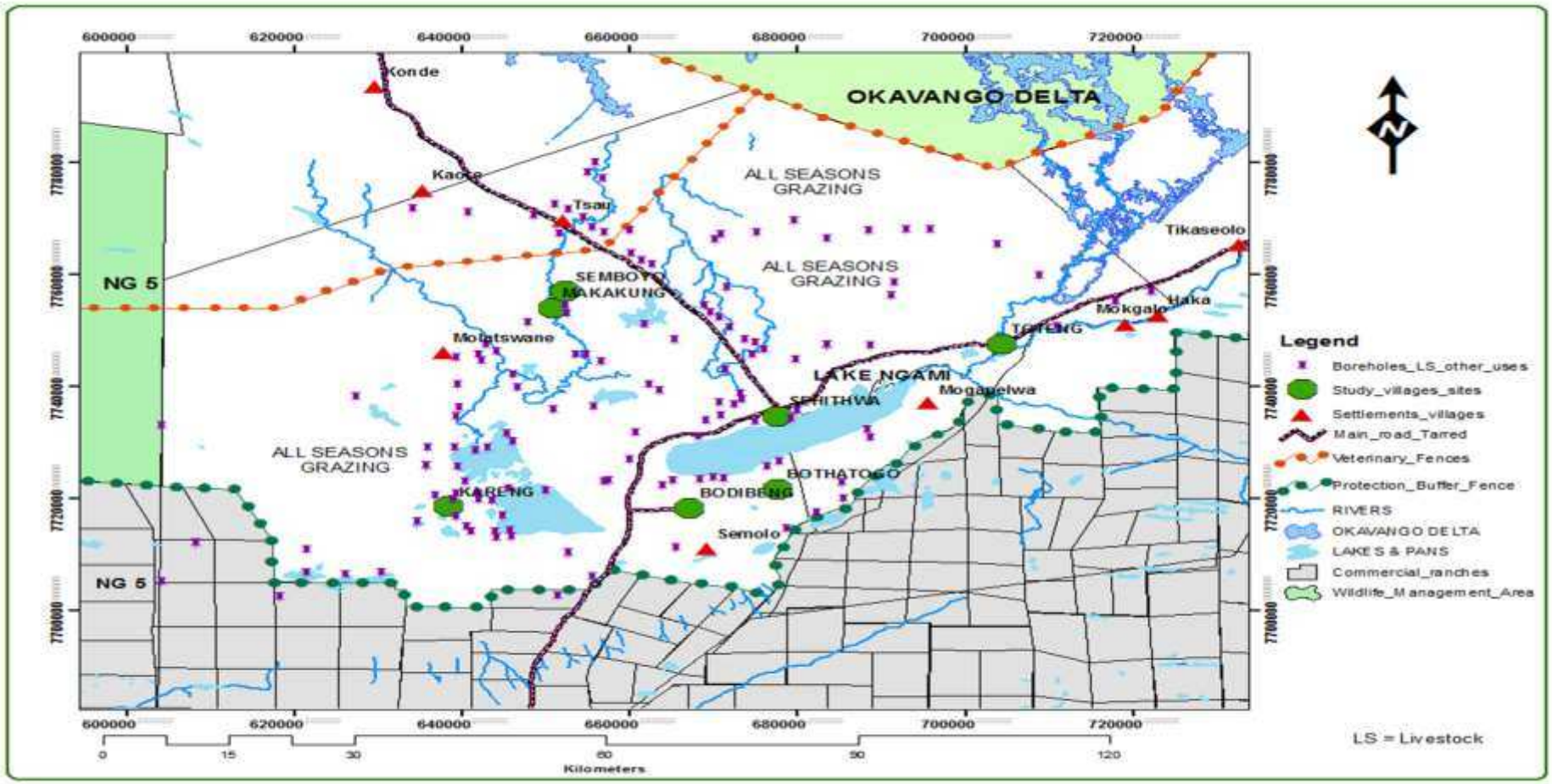

Figure 4: Spatial configuration after the transformations, showing all-season grazing areas after the land tenure transformation.

The significant reduction in the amount of communal grazing lands available was not accompanied by a reduction in cattle numbers as purported by TGLP. Under TGLP, it was assumed that large scale cattle owners would transfer their herds to ranches and leave the communal grazing land to the poor subsistence pastoralists (RoB, 1975). Respondents argued that cattle numbers continued to increase and are currently very high. Opportunistic ranchers with access to privatised land continue to keep large numbers of cattle in communal areas. This allows them access to communal grazing lands and Lake Ngami, and to sell when opportunities for markets arise on either side of the buffer fence. Some ranchers interviewed during focus groups and key informant interviews agreed that they have cattle posts in communal lands. The persistent outbreak of FMD has systematically terminated beef exports in Ngamiland, a factor which also significantly contributes to the continuous increase in livestock numbers in the communal areas as there is no offtake. The livestock trend statistics from the Department of Veterinary Services depicted in Figure 5 indicate a continuing increase in cattle numbers in the communal areas. The increase has possible consequences such as overgrazing and degradation of communal lands as mobility is constrained.

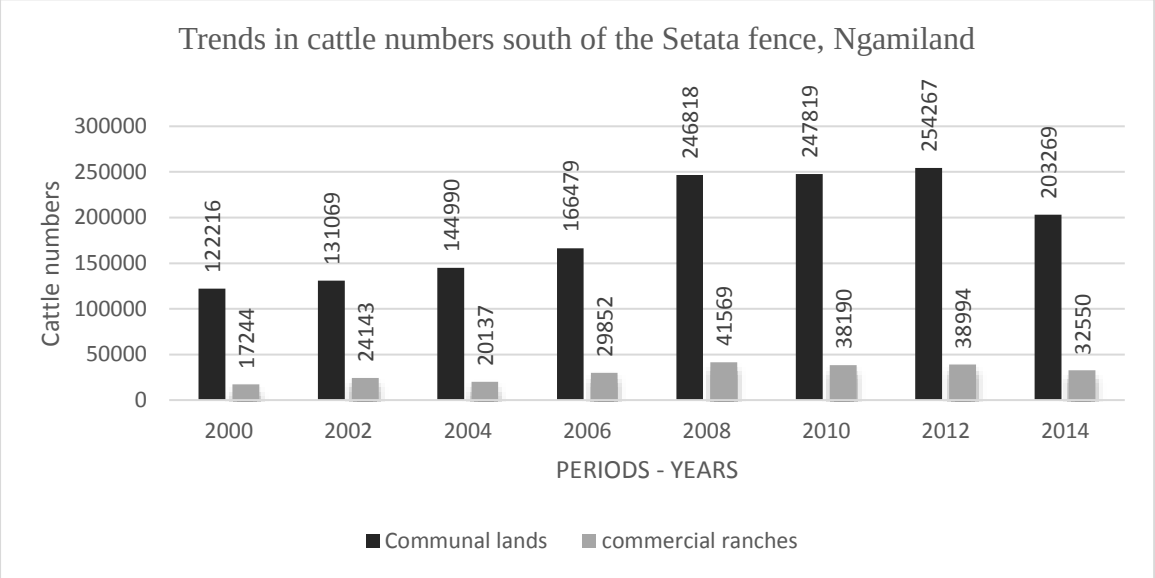

Figure 5: Cattle numbers, 2000 – 2014 Data source: Department of Veterinary Services (DVS)

Respondents argued that current rangelands are congested and heavily over-utilised and that 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 km^2 of all-season grazing areas shared by all villages in the study area, compared to 22,380 km^2 of wet, dry and drought season grazing before the fences.

Approximately 65% of communal lands have 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.

Table 1: A GIS estimate of communal grazing areas before the privatisation policies (km^2)

	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**

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 fences have bisected migratory corridors. *'...*the construction of fences did not give due consideration to animal migratory corridors, fences have diverted animals from their traditional migratory corridors, especially elephants into our cattle posts and arable gardens*...'* (Interview data, 63-year-old male pastoralist, Bothatogo, 2015).

Respondents also assert that control of livestock diseases is difficult because of congestion in communal 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.

3.3. 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. Respondents argued that the government's decision to allow enclosure of natural water pans by private ranches had weakened local rangeland management systems, deprived pastoralists of valuable assets and fostered conflict over the remaining water sources, and contributed to land degradation caused by livestock congestion around Lake Ngami. Competition over access to water between and within land use systems, especially between livestock and wildlife, was also reported to be widespread as most of the natural ponds are now enclosed by private ranches. Only 30% of the 26 respondents interviewed during key informant interviews indicated that they own livestock boreholes of their own. The rest depend on natural water sources or pay a fee to those with boreholes. Respondents 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, respondents argued that most of the underground water is saline and some borehole owners, including ranchers, continue to use natural water sources, ponds, lagoons, rivers and the lake to water their livestock.

3.4. Current land use

An assessment of land use categories within the remaining area (Figure 4) shows a spatial configuration of cattle posts concentrated around permanent water sources, especially around Lake Ngami, settlements, and arable fields. The effects of privatisation and subdivision are reflected mostly in the changing patterns of pastoral land use, including the year-round use of critical grazing reserves that were previously used only for one season each year. Livestock is concentrated near major settlements, roads, rivers and the lake (Figure 6). Pastoralists 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 the 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 pastoral management *system…*the remaining piece of land is *congested and overgrazed…',* (Focus group discussion data, Sehithwa, 2015). The distinction between land use systems, cattle posts, arable lands and settlements is unclear. The area between the lake and the ranches was described by respondents 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 on this zone, pushing the communal pastoralists further towards the villages.

Using land use concentrations and 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, 25,182.25 m from the centre of concentration (Lake Ngami), represents the highest degree of compactness of land use (severe pressure zone). Beyond this distance, the dispersion increases, and therefore land use pressure decreases (moderate pressure zone). Respondents identified the types of land use pressures and their associated impacts (Table 2) during focus group discussions. Figure 6 identifies land use pressure zones. Land use activities are concentrated around Lake Ngami and the ranches; hence, these areas suffer the greatest land use and grazing pressure.

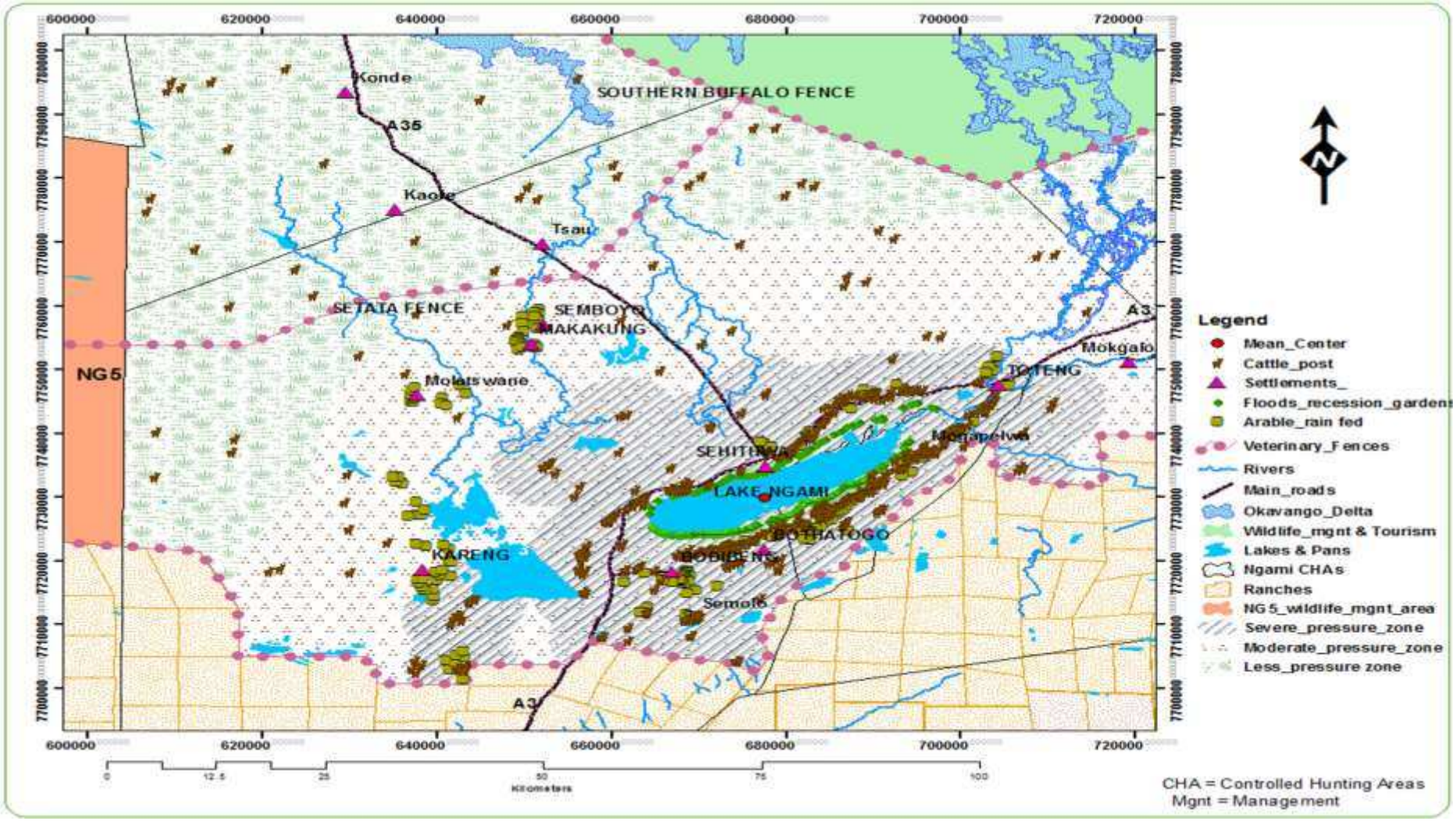

Figure 6: Land use pressure areas (cattle posts concentrations) and other land uses; ranches, arable fields superimposed to identify areas of competing land use using spatial statistics (mean centre and standard distance)

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	Loss 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, difficulty controlling disease incidences, e.g., FMD
Land use overlaps; arable land, cattle posts and wildlife	Land use competition and conflicts; destruction of crops by livestock and wildlife, predation, human-elephant 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

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), to subsistence agro-pastoralists squeezed in the area between the fences where land use and grazing pressures are intense (settlements, arable and cattle posts) especially around Lake Ngami. To the southwest is the contested wildlife management area known as NG5. A network of veterinary fences is followed by a purely commercial wildlife management area and tourism facilities to the northeast, where pastoralist production systems are restricted.

4. DISCUSSION

4.1. Local spatial knowledge, rangeland privatisation and spatial mobility

To cope with environmental variability, pastoralists have developed knowledge and skills (Solomon et al., 2007), including comprehensive systems of seasonal migration and livestock mobility under controlled grazing patterns (Fernandez-Gimenez and Le Febre, 2006). 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. Respondents in this study were particularly wary of problems associated with livestock spatial 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, as common pastures and ephemeral water sources are enclosed for private use and trekking routes are blocked, communal pastoralists bear the effects of ecosystem deterioration.

The findings of this study show that pastoralists in the area used to follow a traditional transhumance pattern of pastoralism with seasonal movement to and from Lake Ngami and surrounding Okavango delta floodplains. Our findings suggest that the loss of critical wet season grazing reserves was due to a failure to recognise the spatial heterogeneity of the Ngamiland pastoral landscape, including diversity within traditional pastoralists' management strategies. This 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. Respondents blamed government policy interventions for the loss of traditional grazing territories, erosion of traditional management institutions, and overall rangeland degradation in the communal areas especially around Lake Ngami.

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 pastoralists' spatial knowledge using participatory mapping and PGIS. This process generated unique spatial knowledge representing traditional grazing systems, pasture boundaries and the impacts of rangeland policies on livestock spatial mobility. It also facilitated a spatially explicit discussion (Talen, 2000), which enabled participants 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 can be identified. Such information can inform planning and/or strategies for resolving land use conflicts in communal areas.

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, Smith, 2003), particularly in sub–Saharan African rangelands. 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. Smith (2003) notes that when mapmaking is done only by government officials or bureaucratic elites, they inherently neglect features of the landscape that are important and the most relevant to local communities. We agree, and argue by extension that analysing pastoral land use using local pastoralists' spatial knowledge allows resource users to depict not only their grazing space but also the relationship between resource temporal arrangements and their spatial functionality.

Respondents reported that it was the first time they had been involved in a project in which they drew their own maps and delineated boundaries. Pasture boundaries, alienation of

productive grazing lands and encroachment by ranches remain sources of disputes between pastoralists, government officials and ranchers. Respondents felt strongly 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, and produce useful cartographic information and empirical evidence regarding problems associated with privatisation and subdivision of communal grazing lands.

The empirical evidence and experience drawn from this research shows that local pastoralists can work with researchers to transform their cognitive spatial knowledge into forms that can inform policy. The basic spatial relationship between local communities and the natural environment in which they make their living is often poorly understood by government planners and/or policy makers (Herlihy, 2003). However, instead of playing an active role in research agendas, pastoralists are often the subject of research (Vetter, 2005). Their needs, priorities, and environmental and spatial knowledge are often omitted from policies that directly affect them. Participatory mapping and PGIS 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, and provided 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 transformations that have taken place in Ngamiland since 1975.

5. CONCLUSIONS

This study demonstrates how participatory mapping and GIS can be used to foster better articulation and understanding of pastoralists' tenures and grazing patterns. Respondents from all focus groups lamented diminishing communal grazing lands and constriction of livestock spatial mobility as ranches have taken large tracts of land out of communal ownership. Respondents argued that animal health and rangeland policies do not recognise their traditional

resource rights, grazing territories and management systems. Efforts to negotiate with authorities have been difficult mainly due to a lack of documented spatial information for their grazing territories. The local authorities observed the value of participatory mapping as a way of producing empirical evidence and detailed information that they can use to engage relevant government entities, defend their grazing space against expropriation by state or opportunistic elites, and help them manage their resources in a sustainable manner. This study reveals that local pastoralists are endowed with a wealth of spatial knowledge about their grazing territories. This knowledge is rarely documented or incorporated into conventional government planning processes. The PGIS approach produces valuable pastoral land use and spatial information vital to the sustainable management of land in dryland environments, where mobility and resource access remain at the core of pastoral sustainability. As communal lands continue to shrink and prospects for sustainable pastoralism become 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 changes.

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