The Challenge Of Sustaining Pastoralism Land Tenure System For Ecological Conservation Of The Maasai Mara

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Abstract: In the Maasai Mara ecosystem, nomadic pastoralism remains a dominant form of land tenure where pastoralists align their livelihoods with seasonal cliamte variations by systematically moving their livestock to different feed locations. In recent past, nomadic pastoralism in the Maasai Mara is challenged by the concept of private property where conventional private property regimes seek to allocate individual rights to land traditionally over a fixed and well-defined areas, including group ranches. Following the period of decolonization in Africa, implementation of these programmes became popular worldwide, even in regions with arid and semi-arid climate. However, pastoralism as a tenure system persisted and conflicts soon ensured with the individual property owners; and contemporary drivers, many underpinned by climate change agenda, further complicate these tenure conflicts.

Despite all the conflicts and the value of pastoralism in ecosystem conservation, spatial information about pastoralist's tracks and migration corridors often remain undocumented. Consequently, the spatial information about pastoralism has not been incorporated in the local land information systems or land use planning. The situation is worsening as land is continuously being surveyed, demarcated and allocated for private purposes. Social and economic welfare among pastoralists has declined as it depends on the freedom to access water and grazing areas. The challenge is therefore to inventory the cattle tracks and migration corridors, and include this information in local land information system, so that it may contribute to better planning, and alleviating the problems resulting from depriving the pastoralists access to the daily and seasonal resources.

This paper therefore set out to look into the changing pastoralist land tenure (and land use) regime in the Maasai Mara concervancy, in Kenya, and proposes innovative geospatial-based methodology for comprehensive documentation of the pastoralist routes as a means of understanding climate change induced migration and thereby plan how pastoralism can be better sustained for better ecological management.

Keywords: Pastoralism, Private Property, Conflicts, Spatial Documentation

I. INTRODUCTION

A pardigm shift has taken place within the wider global land administration community where individual land titling, on its own, cannot deliver security of title to a majority of people in the developing world and is slower than is required. At the moment, only 30-50 countries in the world maintain complete land tenure administration systems: roughly 75% of the global population does not have access to formal land tenure security [Romberg, 2012]. This means that approximately 4 billion people, out of the 7 billion world population, land interests are not recorded in the official land register or known by government [Zevenbergen, 2012]. Many of these people are found in Sub-Saharan Africa (SSA), where land documentation systems are in various stages of development or decay.

The global land administration community has accepted that the way forward to deliver security of tenure is through a continuum of land rights, which allows poor people to get onto the property ladder [Zevenbergen et al., 2012]. The community argues that less conventional forms of land tenure should be recognized and afforded better forms of security and protection. The innovative continuum of land rights approach if implemented at scale will require the introduction of new forms of land rights documentation. The aim is to differentiate these new approaches from the conventional land recording systems which were developed in Western European countries over many centuries and proliferated during global colonization [Zevenbergen, 2012]. The contemporary out-comes of these developments are highly centralized, highly accurate, and highly accessible digital land records, but only in the most developed countries.

These modern systems come with their own best practices and assessment schemas. Many attempts to transplant these systems in the less developed countries, customary, or communal areas have met with mixed results [De Soto, 2000]: as institutional systems are generally lacking, which take decades even centuries to build. Consequently recording tools that work within the confines of existing norms and approaches in land administration are lacking. This requires development and deployment of new innovative tools in order to capture the missing land tenure systems onto the local register; one such tenure is Nomadic pastoralism.

II. PASTORALISM

Pastoralism is a major land use in the arid and semi-arid rangelands all over the world. Pastoralists typically rely on animal husbandry for their economic survival. The arid environment in which the pastoralists find themselves is characterized by erratic rainfall distribution and varying climatic conditions under which plant growth is seasonal. The strategy of the pastoralists to provide year-round supply of food to their animals involves moving the livestock to pasture rather than bring fodder to the animals [Lengoiboboni, 2011].

In the dry seasons therefore, pastoralists move their livestock to the highlands or well-watered pastures and when the rains fall on the rangelands, they move back to take advantage of the new and more succulent pastures. This movement between rangelands and dry-season grazing areas allows the farmers to exploit ASAL resources in the different agro-ecological conditions at different times to make for the fluctuations in production. The movement also ensures a balanced maintenance of the ecosystems so that the pastures have time to rejuvenate and support the pastoralist's life-style for a long time. Pastoralists land tenure system is based on customary conditions where pastoralists hold their land in communal nature.

This communal property regime is important because it creates pastoralists right of access. It also provides a reliable framework for the pastoralists to exploit the available resources across various agro-climatic conditions and thereby reducing their level of vulnerability. Lengoiboni [2011] has referred to this tenure system as spatiotemporal in the sense that pastoralists own land across the ecosystem of movement and at different times in the year. In the Maasai Mara region, pastoralism has moved from Nomadic to sedentary and currently the main form of pastoralism is the agro-pastoralism, where the livestock movement is tamptered with sedentary agriculture.

The formalization of tenure in Kenya from the 1950s, through land adjudication and consolidation, had the impact on the extensive seasonal migrations of the pastoralists because it endangered the traditional methods of access to local resources. Surges in large-scale foreign invetment in land, increased nature conservation activities, growth in tourism, forest depletion, oil and mineral extraction programes all increase tensions between the different stakeholders; and it is the pastoralism who often lose out in these climate change inspired conflicts. While pastoralists are intrinsic climate change adaptors, they are weaker economically and legally. Unlike other land uses, pastoralism activities are not always assured by national land policy and administration frameworks. Private ownership is often given precedence over customary land tenures.

Despite policy and legislative movements, approaches for practical recording remain unclear: knowledge on how to record pastoralism tenures in a manner that ensures sustainable ecosystem conservation is almost non-existent. Whilst pastoralism has been widely studied and some routes recorded (Figure 1), many remain undocumented: only vague ideas exist of how pastoralists move. Moreover, the climate change induced shifts in migratory routes are also unknown. Conventional land administration tools are not equipped to capture of manage pastoralist tenures.

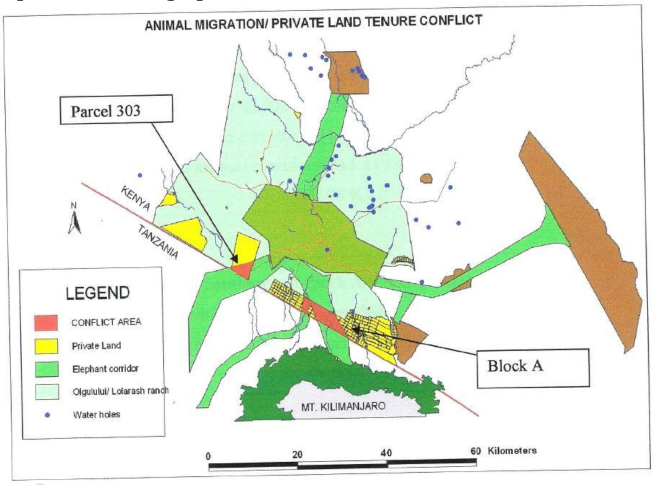

Figure 1: Example of conflicting tenures (Wayumba and Mwenda, 2006)

The climate change adaptation offers an opportunity to develop methodologies for recording pastoralism. Currently, there is a general agreement that pastoralism has a major role in supporting sustanable ecological and economic systems. Moreover, the limitations of conventional private property approaches are clear as the National land Policies already reflect the changing ideology [MoL, 2007].

The challenge is to operationalize the new ideology. Many studies focus on understanding the status quo: pastoralism actors, related resources, and various interactions are studied. Others seek solutions. Clear acceptance of pastoralist tenures at all levels is an important ingredient in operationalization: all successfully secured formal land tenures rely on clear descriptive and spatial identification. Fit-for-purpose adjudication, mapping, and recording processes deliver this point of authority to communities, governments, and NGOs. Understanding the spatial and temporal aspects of migratory routes will assist in developing this authority. Conventional land administration tools are not well equipped to capture the pastoralist tenures.

This paper proposes innovative methodologies for documenting the pastoralist land tenure regime in the Maasai Mara as a basis for comprehensive environmental analysis and understanding the impact of climate change agenda on the migration routes.

III. TECHNICAL APPROACH AND METHODOLIGIES

Currently, there are at least five main geospatial technologies that are suitable for mapping in the arid and semi arid environments without too much interaction with the ground. These are the Global Satellite Positioning System (GPS), the Unmanned Aerial Vehicles (UAV), Satellite Remore Sensing, LIDAR and Cadastral Modelling. These technologies are herein discussed in terms of their suitability in mapping and documenting pastoralist migration routes in the Maasai Mara conservation area in Kenya.

A. GLOBAL POSITIONING SYSTEM (GPS)

The GPS is a satellite-based radio-positioning and time-transfer system developed by the U.S Department of Defence to support real-time navigation anywhere on the Earth [Parkinson and Spilker, 1996]. The system has the advantage of being globally accessible, funtioning independent of the weather conditions, and being able to provide three dimentional position, velocity and time in a common geodetic refrence system, anywhere on or near the surface of the Earth, on a continous basis [Ogaja, 2002].

Global positioning works by measuring ranges to a number of satellites with known coordinates and thereby the position of the receiver may be computed through mathematical relationships. The two fundamental GPS measurements for position determination are the *pseudorange* and *carrier phase* observations. The basic observation equations for these measurements are [Ogaja, 2002]

$$P_r^s \; - \; \rho_r^s + d\rho^s + c\,(dt^s - dT_r) + d^s{}_{ion} + d^s{}_{trop} + \varepsilon(p_{rx}) + \varepsilon(P_{mult})_r^s \quad (1.1)$$

$$\Phi_r^s \; - \; \rho_r^s + d\rho^s + c\,(dt^s - dT_r)\; \lambda N_r^s - d^s{}_{ion} + d^s{}_{trop} + \varepsilon(\Phi_{rx}) + \varepsilon(\Phi_{mult})_r^s (1.2)$$

The true range, or geometric range, from the receiver to the satellite (Figure 1.1) can be represented in terms of the World Geodetic System 1984 (WGS-84) coordinates:

$$P_r^s = |\, r^s - r_r \,| = \sqrt{(x^s - x_r)^2 + (y^s - y_r)^2 + (z^s - z_r)^2} \qquad (1.3)$$

Where

P_r^s -is the geometric range from the receiver to the satellite (m)

r^s -is the satellite position vector referenced tot eh WGS – 84 (m)

r_r -is the receiver position vector referenced to the WGS – 84 (m)

x^s, y^s, z^s - are the receiver WGS-84 Coordinates

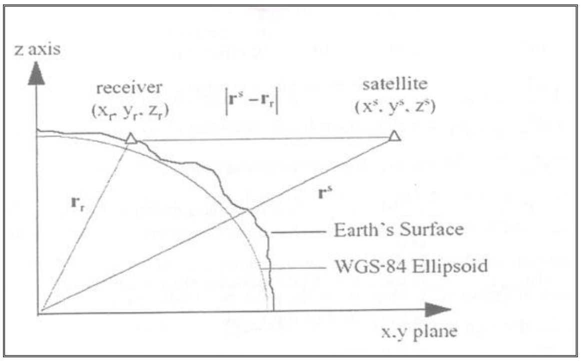

Figure 1.1: Geometric ranges from a receiver to a satellite

The GPS can be used in a variety of modes providing various levels of positional accuracy. The most accurate, real-time positioning mode is known as the Real Time Kinematic (RTK), where two or more recivers are used. However, for mapping of nomadic pastoralism a kind of mobile RTK model is proposed. This model works by fixing a collar GPS around the Livestocks neck or at the tip of the horn so that it can communicate with a base station kept away from the migration area.

The base station GPS acts as a refrence system for the Livestock movement onto reference grid system such as the UTM (1960 Arc Datum), the WGS 84 system or an internationally brefrence system such as the International Refrence Frame (The ITRF). The coordinates of the migration path are automatically genereted from the GPS measurements and refrenced to a digital location on the computer for monitoring and anylis. These measurements can also be plotted onto a topo-map of suitable scale for ground verification and tracking. In Kenya, the Kenya Wildlife Service has used this method extensively to monitor the movemnt of elephants and other wildlife for better range management in the major wildlife conservation areas (Fig. 1.2).

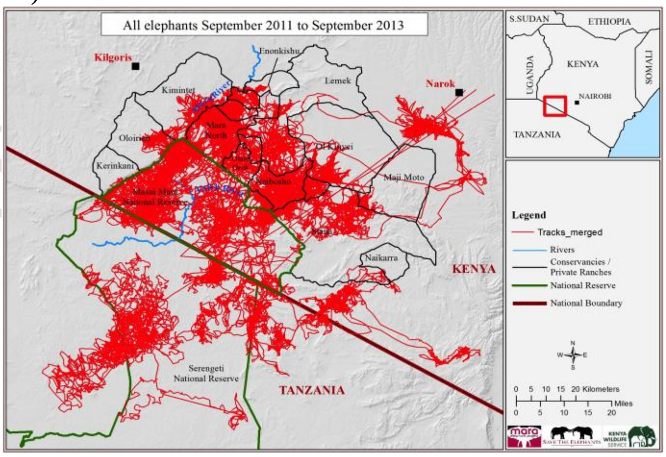

Figure 1.2: GPS Mapping of Elephants Migration in the Maasai Mara (Source: Mara Elephant Project)

B. THE UNMANNED AIRCRAFT VEHICLES (UAVS)

The Unmanned Aircraft Vehicles are fixed-wing or rotary technologies, remotely piloted, and capable of carrying geospatial and imagery sensors for data collection. The emergence of these small and affordable unmanned aircraft vehicles (UAVs) technology and recent advances in highly automated mapping techniques offer a new tool and methodology for producing faster and cheaper spatial data that can benefit land administration agencies and help secure property rights for millions around the world [Kelm, 2014].

Their main advantages over traditional (manned) airborne-based mapping are: i) flexibility - easily deployable and individual flight patterns; ii) so far unrivaled image resolution - a ground pixel size of 3cm can be realized at ease; iii) and ease of use - with a small training effort, state-of-the-art devices can be operated even by laymen (iv) it is suitable for both urban and rural surveys at a relatively cheaper cost,

(v) it is flexible, inclusive and participatory, as property owners can identify their boundaries and assist in ground truthing, (vi) it provides high spatial resolution orthorectified imagery which can be used by Land Administration professionals instantly, without waiting for elaborate processes away from the study site, (vii) the system is easily upgradable in the sense that several imagery can be acquired over a period of time and used to assess changes on the ground. This is particularly suitable for mapping in the Arid and Semi Arid environments where pastoralism is dominant.

In this project, UAVs are recommended for mapping the migration routes as the livestock move from place to place and recording the movement on high spatial resolution satellite imagery such as the Google Earth. This way, it will be possible to follow instantly, the migration routes and correlate them with the existing land use and land cover patterns. One major drawback with the use of the UAVs in Kenya is that special operation permits must be obtained from the Government due to the prevailing security issues in the country.

C. REMOTE SENSING TECHNOLOGY

Remote sensing is defined as the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation [Lillesand and Kiefer, 2000] or the science and technology of gathering and processing reliable information about objects and the environment with out direct physical contract. Of most significant impact are systems using force fields of the electromagnetic spectrum which permit the user to directionally separate the reflected energy from the object in images. Remote sensing was introduced in Kenya in the 1950s when aerial photographs were incorporated in the land consolidation programmes to assist in the computation of percentage cut and the reconciliation factor.

Immediately after independence in Kenya (in 1963), it was recognised that the land consolidation program, which was first implemented in Central Kenya, was too slow to deliver titles urgently to the new state. The Government set up a Commission under J.D. Lawrance to recommend ways of accelerating the programme. The Commission published its findings in 1966 and one of its major recommendations was the adoption of aerial photography as a means of mapping land holdings in the previous Native Reserves. Adams [1969] tested suitability of Arial photography at North Tetu in Nyeri and recommended that ortho-rectified aerial orthophoto were suitable for the adjudication instead of the ground-based methods.

However, due to high demand for titles and political reasons, the use of orthorectied was abandoned and land adjudication in Kenya was carried out with unrectified aerial photographs to the present day. Several authors, Ondulo et al. [2015] have observed that the use of unrectified photos has caused a lot of distortions in the cadastral boundaries in Kenya. Furthermore, the acquisition of these photographs is expensive as aircrafts have to be deployed every time such photographs are required.

Lemmens et al. [2009] have demonstrated that high spatial satellite imagery may be a viable alternative to the aerial photos in land adjudication in Africa. The use of satellite imagery for cadastral application is however not new. Ondulo et al. [2015] have advocated for the use of the technology in land adjudication. However, the spatial resolution has not been adequate for the very small land holdings in Africa; and it is only recently that imagery with high enough spatial resolution have been made available for cadastral surveying. Studies in Ethiopia, confirm that satellite imagery such as the Quickbird (at 60cm) resolution can be used as the base for data collection. Extracts representing land size of 1km by 1km were plotted on a 1: 2,000 scale as a basis for data collection. This allowed for the identification and plotting of parcel boundaries from the smallest land units in the area. Georeferencing was conducted with hand-held GPS equipment with a nominal positional accuracy of 14m.

Currently, the GeoEye satellite imagery in the form of Google Earth provide a higher spatail resolution of 40cm, which is quite suitable for mapping in the rural areas of Kenya. This paper therefore recommends the use of ortho-rectified Google Earth imagery for mapping of the pastoralist migration routes. When combined with GPS coordinates, the migration routs can be georefrenced onto the UTM (1960 Arc Datum) or in the WGS 84 coordinate system.

D. LiDAR TECHNOLOGY

The measurement principal used in LiDAR data capture is that of range measurement of an oriented laser beam from a platform whose three dimensional (3D) co-ordinates are known. The platform for aerial LiDAR measurements is either a fixed wing craft or a helicopter. The total distance resulting from the range measurement is given by multiplying the pulse return time by the speed of light. The distance to the Earth's surface, or sample point, is half the total distance of the return pulse. The physical attitude, i.e. the position and orientation of the sensor, is calculated from **G**lobal **P**ositioning **S**ystem (GPS) and **I**nertial **N**avigation **S**ystem (INS) data. The INS is also known as an **I**nertial **M**easuring **U**nit (IMU). In combination with the scan angle (the angle with which the laser beam is deflected from nadir) measurements, the 3D position of each laser spot on the Earth's surface is determined (Ayugi, 2006). Figure 2-1 illustrates the principle of LiDAR data capture.

Figure 1.2 illustrates various parameters associated with LiDAR. There is the flight height h and the maximum scan angle θ_{max}, also termed the **f**ield **o**f **v**iew (FOV). The instantaneous field of view, given by θ, is the current scan angle and γ the divergence of the laser beam.

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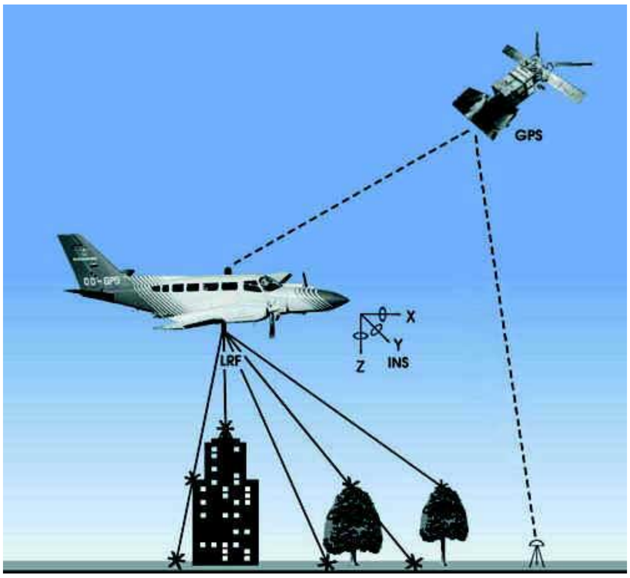

Figure 1.2: Principles of LiDAR data capture (Source: Ayugi, 2006)

This divergence is brought about by the fact that the laser beam is not truly collimated, resulting off nadir in an ellipse of light on the Earth's surface. The swath width, SW, and the diameter of the footprint D can be derived as shown in the equations (1-1) and (1-4).

From equation 1-1, the swath width is directly proportional to the product of the flying height and the tangent of half the maximum scan angle. Any increase in either of these two elements will result in an increase in the swath width. From equation 1-4, the diameter of the laser footprint is directly proportional to both the flying height and the angle of divergence. Any increase in either of these two elements will result in an increase in the laser spot or footprint diameter. The footprint diameter is, however, inversely proportional to the square of the cosine of the swath angle.

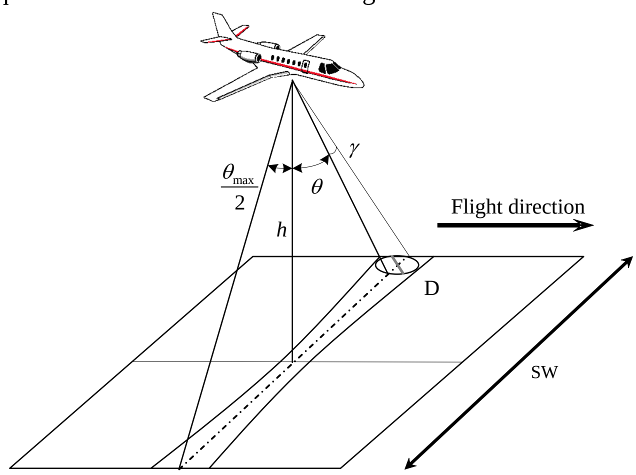

Figure 1.1: LiDAR ranging geometry (Ayugi, 2006). SW is the swath width, h the flying height, D the laser footprint diameter, θ the inclination angle and γ the beam divergence

$$SW = 2 \cdot h \cdot \tan \frac{\theta_{max}}{2} \quad (1\text{-}1)$$

$$D = h \cdot \tan(\theta + \gamma) - h \cdot \tan\theta \quad (1\text{-}2)$$

Using trigonometric algebra:

$$\tan A - \tan B = \frac{\sin(A-B)}{\cos A \cdot \cos B} \quad (1\text{-}3)$$

Equation 5-2 becomes

$$D = h \cdot \frac{\sin(\theta + \gamma - \theta)}{\cos(\theta+\gamma)\cdot\cos\gamma} = h \cdot \frac{\sin\gamma}{\cos(\theta+\gamma)\cdot\cos\gamma} \quad (1\text{-}4)$$

But $\gamma \approx 0$ rad, $\sin\gamma \approx \gamma$ and $\theta + \gamma \approx \theta$ (1-5)

$$\therefore \quad D \approx \frac{h}{\cos^2\theta}\cdot\gamma$$

It should however be noted that as an angle increases from 0° to 90° the cosine of the angle reduces from 1 to 0. The cosine function is therefore less than 1 but decreases with an increased swath angle. Hence, an increase in the swath angle also results in an increase in the diameter of a foot print. Nevertheless, a footprint has its smallest diameter at nadir and this diameter increases to a maximum value at maximum swath angle. The application of LIDAR in mapping the pastoralists migration routes would involve deployment of aerial phoography equiped with LIDAR and GPS facilities. ThE GPS would provide the planimetric coordinates of the migration routes while LIDAR would give the height value (refreered to mean sea level). These LIDAR data would be useful in the construction of the Digital Terrain Model (DTM) and Digital Surface Models (DSM) when required for planning purposes.

E. DEVELOPMENT OF LAND INFORMATION DATABASES

Generally, Land Information Systems can be developed as Relational Database Management Systems (RDBMS), Object Oriented Database Management Systems (OODBMS), or a hybrid of both the Relational and Object Oriented. The hybrid system is prefered in spatial modelling as it is supported by a robust GinisNT and Mediator systems which facilitates the operation between the RDBMS and OODBMS. While the purely Relational Model relies on joins for query operations, the hybrid system uses REALATES to access information in both databases, which is particularly suitable where spatial data analyses are concerned.

In developing theLIS, all the non-spatial attributes will be keyed in Microsoft Excel. These data will include; names of owners of the land parcels through which the pastoralists pass, their identification card number, use of the land, and the entire household of the parcel owner or, and all the necessary details that may assist in the identification and mapping of the pastoralist routes. The spatial data will be derived from the UAV photography, old maps and satellite imagery such as the Google Earth. All the migration routes will be mapped by the consultants and citizens through participatory mapping approac. Digital sketchmaps will be used by the citizens to sketch out the migration routs from their memory and general knowledge of the local environment. Bennet [2015] has demonstrated that sketchmapping method is an effective tool for citizens participartory mapping and substantially complements the traditional mapping approaches.

What makes smart sketch maps "smart" is the fact that explicitly drawn spatial object are identified and assigned a semantic category. This makes them amenable to manipulation and deeper analysis. To achieve this "semantic recognition" a sketch map must first be segmented and the resulting segments classified into some semantic category. This task will evolve the theory and tools for semantic object recognition previously developed at the University of Twente in the Netherlands. The semantics applied to recognized objects will come from the extended Land Administration Domain Model.

The utility of sketch maps within a land administration system comes mostly from their ease of use and their ability to capture non-geometric spatial information. In this task methods will be developed for spatially aligning sketch maps with georeferenced maps or images in order to facilitate the transfer or integration of the ambiguous non-spatial information carried by the sketch map into the geometric data that mostly characterizes land administration information systems. Alignment involves identifying unique landmarks (e.g. roads, trees, and the pond etc) and using them to anchor other information in the sketch map over the georeferenced map. Studies done by the USAID-based African Development Solutions (ADESO) confirms that sketch mapping can provide a viable tool for mapping pastoralist migration routes.

Finally, both the attribute data and spatial data will be loaded onto the Social Tenure Domain Model (STDM), which is basically an Internationally Certified Cadastral Model for informal Settlements. Through the STDM system, it will be possible for the client to query any of the attribute data and spatial data according to need. The consultants have been able to test the suitability of the STDM in mapping of several informal settlements in Kenya [Wayumba et al., 2015] and the results are quite impressive. Basically, the STDM provides a Land Information Management Framework that integrates formal tenure, informal and customary tenures, as well as integrating administrative and spatial components.

The STDM makes this possible through the use of tools which facilitate recording of land rights, restrictions and responsibilities as required in a standard Land Administration Domain Model. Although this project is about mapping pastoralists migration routes, there are several other tenure systems which will benefit from the exercise. Because the STDM is designed to take care of all these tenure types, it was found most suitable for the project. However, where there are specific land tenure needs, the software will be modified to address such situations.

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