Linking Land Tenure and Use for Shared Prosperity
ANNUAL WORLD BANK CONFERENCE ON LAND AND POVERTY
WASHINGTON DC, MARCH 23-27, 2015

Harnessing Pastoral Knowledge for Climate Change Adaptation in the Drylands

Hill, Chris (1); Hesse, Ced (2); Zwaagstra, Homme (1); Harfoot, Andrew (1), Rowley, Tom (3)

1: GeoData, University of Southampton, United Kingdom; 2: International Institute for Environment and Development; 3: Independent researcher

cth@geodata.soton.ac.uk

Paper prepared for presentation at the

"2015 WORLD BANK CONFERENCE ON LAND AND POVERTY"

The World Bank - Washington DC, March 23-27, 2015

Abstract

Experience from Kenya and Tanzania using a GIS workflow is presented that enables pastoral communities to validate and demonstrate, in a 'language' understood by policy-makers and planners, the logic behind their livelihood strategies. The work is being carried out within a broader context of political and administrative devolution where County and District governments in Kenya and Tanzania, respectively, have authority over local planning and development processes, and where the policy and legal environment is increasingly supportive of pastoralism. The challenge lies in the implementation of these policies and laws, and their reconciliation with other laws that often have conflicting provisions over land and natural resources. Through improved understanding as a result of the geospatial resource mapping work, OpenData and open licensing policies it is anticipated that governments, at national and local level, will begin to invest in appropriate planning to support pastoralism as a viable and productive livelihood and economic system under increasingly variable climate conditions.

Key Words:

Community Participatory Mapping, Geographic Information System (GIS), Arid and Semi-arid Lands (ASALs), Pastoralism, Climate Change Adaptation.

SUMMARY

Pastoralists in Africa use detailed knowledge of their environments, characterised by highly variable and unpredictable resources, to maximise livestock productivity and minimise asset loss (Krätli and Schareika, 2010). Variable rainfall in time and spaces results in an uneven and unpredictable pattern of pasture growth across the rangelands. As the nutritional quality of plants change during their growing cycle, the availability of nutritious pastures in any given place is temporary and short-lived (Bremen and de Wit, 1983; IIED & SOS Sahel, 2009). Different plant species, different soils and different topographical features, such as gullies or depressions where water may concentrate, add further complexity and dynamism to the nutritional profile of East Africa's rangelands (Behnke et al., 1993).

Under properly functioning pastoral production systems in the rangelands, the spatial and temporal variability in the availability of nutritious pastures is not a constraint for livestock productivity: in fact it is a resource. Through mobility, the selective breeding of livestock, the maintenance of the commons and the practice of negotiated access to resources, pastoralists can harness and exploit the ever-changing concentrations of plant nutrients on the rangelands for livestock production (Krätli, 2007; Krätli and Schareika, 2010; Krätli et al., 2013; Wilson & Clarke, 1976).

A range of competing land use activities are increasingly threatening livestock mobility and secure access to high-value pastoral resources, such as wetlands and riverine forests (Niamir-Fuller, 1999; IIED & SOS Sahel, 2009). The steady encroachment and alienation of pastoral resources over much of East Africa, from family and commercial farming, conservation, hunting and mining has undermined pastoralism as a livelihood and economic system. This is contributing to increased poverty, land degradation and conflict in many pastoral areas (Catley, Lind & Scoones, 2012).

Poor understanding by policy makers and planners of the rationale of pastoralism (and its significant contribution to local livelihoods and the wider economy compared to other land uses in the same environment), partly explains why policy and planning has failed to enhance pastoral mobility and protect the rangelands from further encroachment (Hesse & MacGregor, 2006; Hatfield & Davies, 2007; Behnke, 2006, 2008, 2010; Krätli, 2014). The inability of pastoralists to articulate the deep knowledge they have of their environment, and how they utilise it, compounds the problem.

Ruling national elites and powerful global economic players frequently use narratives about environmental degradation, resource scarcity and low economic productivity to justify policies that promote the large-scale appropriation, fragmentation and conversion of the rangelands to alternative uses: uses that themselves are often major drivers of environmental degradation, resource scarcity and

ultimately failed economic development (Leach & Mearns, 1996; Keeley & Scoones, 2000; Galvin et al., 2008; Krätli & Enson, in press). Large-scale agricultural irrigation and mechanisation schemes, as well as ranching or export-oriented agribusiness, have a track record of short-lived returns and a heavy ecological footprint in the drylands. They also often displace existing ecologically compatible and economically viable livelihood systems, and contribute to the disenfranchisement and pauperisation of small-scale producers (Behnke and Kerven, 2011).

Participatory or community mapping is a component of the wider 'participatory toolbox' (Chambers 1994), described within the context of Participatory Rural Appraisals. It allows local knowledge of livelihoods to be shared, and community level contributions to information and analysis. Participatory mapping, as a 'geographic diagramming' approach, generates mental maps by the individual or group based on their insights, experience and priorities. Participatory GIS (PGIS) combines digital mapping with these methods (Dunn 2007).

PGIS can make use of a range of geospatial sources, such as aerial and satellite data, 3D physical models (P3DM) and field data from GPS (Rambaldi et al. 2006). Previously PGIS approaches have rarely captured the attributes of features described by local people, temporal information, or made allowance for the assembly of multiple community maps within a single platform - particularly in arid and semi-arid lands (ASALs). Nor have they planned for the long-term management and distribution of collated data.

Whilst GIS may be common at national levels in the drylands, and form part of a spatial data infrastructure and planning system, it is rarely developed at the sub-national levels (e.g. county, district, or community). National level maps often have little topographic or thematic detail on the rangelands, which tend to be represented as 'vast and empty'. The application of participatory GIS allows the capture of local community knowledge and the spatial presentation of these highly complex ecological, social and economic landscapes. The challenge remains however of how to ensure this local knowledge can be given due recognition and weight in policy development and decision-making.

Presenting information held by the community in the form of a map is a powerful way of compelling others to recognise the value of local knowledge for planning and resource allocation. Valid, reliable and accurate digital maps can also be independently verified, and therefore gain more traction in decision-making processes. Digital maps can act as an effective 'loudhailer': amplifying the impact of community voices at all levels, allowing information to be retained by the community, and forming a basis for monitoring and evaluation. Using arguments referenced to a geographic coordinate system can bring evidence-based, local knowledge to bear on planning and decision-making in a way which is much more difficult to discredit or disregard. The approach also allows different perspectives to be combined -

including gender-specific views and those of stakeholders at different levels - with information shared on a common platform.

The provision of data geospatially also enforces a structure to the information: it is digitally stored and managed, it enables visualisations, and it can be integrated with other information thereby enhancing communication at governance levels. Developments in Open Source software, advanced visualisations - including digital earth technologies, mobile data capture, cloud storage and Open Data philosophies present new opportunities for enhancing the power of participatory mapping. These approaches have the potential to reconcile community-held knowledge with formal government planning processes.

This paper presents on-going experience from Kenya and Tanzania using an improved mapping system and workflow that enables pastoral communities to demonstrate, in a 'language' understood by policy makers and planners, the logic behind their livelihood strategies. The work is being carried out within a broader context of political and administrative devolution where County and District governments in Kenya and Tanzania, respectively, have authority over local planning and development processes, and where the policy and legal environment is increasingly supportive of pastoralism.[1] The challenge lies in the implementation of these policies and laws, and their reconciliation with other laws that often have conflicting provisions over land and natural resources. Through improved understanding as a result of the mapping work, it is hoped that governments, particularly at the local level, will begin to invest in appropriate planning to support pastoralism as a viable and productive livelihood and economic system under increasingly variable climate conditions.

METHODS

LOCATION

The participatory mapping work is being implemented as part of two complementary climate change adaptation projects in northern Tanzania and Kenya (Figure 1). These two projects are intended to inform drylands development planning and strengthen local government and customary institutions' roles in adaptive and climate resilient development. Pastoralism, the dominant economy and livelihood in both areas, competes with conservation, wildlife-based tourism, and to a lesser extent crop farming, for access

---

[1] The new Constitution of Kenya (2010) specifically recognises land rights of communities, including pastoralists; the National Land Policy (2009) has specific provisions aimed at securing pastoral land rights; and the recent National Policy for the Sustainable Development of Northern Kenya and other Arid lands (2012) is explicit on the recognition of pastoralism as the dominant economy in the country's drylands. In Tanzania, the National Land Policy (1995) is supportive of community land rights in that it proposes devolution of authority over village land to the village level, and has provisions to secure the land rights of smallholders including pastoralists.

to land and important renewable natural resources. The area mapped within the programmes currently amounts to 4% of the land area of Kenya and 0.9 % of the land area of Tanzania[2], with five counties in Kenya and three in Tanzania intended for resource mapping.

Figure 1 Location of ASAL participatory mapping programmes in Kenya and Tanzania.

Tanzania project title: Promoting adaptation and climate resilience growth through devolved district climate finance (2013-14), funded by DFID[3] **. Kenya project title**: Climate adaptation in the ASAL counties of Kenya (2013-16), funded by DFID.[4] http://www.iied.org/drylands-pastoralism.

FRAMEWORK

The framework for participatory mapping within these two projects is based on the 'theory of reasoned action' (Fishbein and Ajzen, 1975), or the model of behaviour change as a key to sustainable decision-making. This simple model proposes that presenting the community's perceptions, knowledge and priorities can result in behaviour change (of planners and decision makers), and that change can be triggered through increased knowledge based on systematic review and reasoning. Although this simple model can be challenged (Burnes 2004), it is thought that a better appreciation of the range of factors and barriers mediating between information and behaviour is relevant to the design of the participatory mapping process. The focus here is on the technical collation of information that can contribute to lowering barriers to action. Capturing and collating customary knowledge in a spatially explicit way helps to present and understand the regional use, livelihoods, resilience and adaptation strategies applied by pastoralist communities. At a practical, project level this framework is fundamental to the 'Theory of Change' that seeks to improve the quality of planning at District level to increase local adaptive capacity, whilst also promoting climate resilient growth and development.

Following the theory of change, the approach to participatory mapping has adopted GIS activities within community workshops to allow for the creation of integrated, consistent and standardised geospatial information.

THE NEED FOR ACCURATE MAPPING

---

[2] Isiolo County 25,336 km^2 area of Kenya 581,309 km^2 = 4%, Longido 8,401 km^2 Tanzania = 945,203 km^2 = 0.9 % of country.

[3] This project builds on an earlier project entitled Mainstreaming climate change adaptation in drylands development planning in Tanzania (2010-12) Funded by DFID, CORDAID and GORTA.

[4] The current phase builds on an earlier project entitled 'Supporting local climate resilience through innovative district funding and social protection mechanisms in the drylands of Kenya' (2012-13). Funded by DFID and CORDAID.

Pastoralists' security over their land and resources is partly dependent on their being able to demonstrate to government and other external actors the spatial extent and the manner in which they use these resources. Few, if any, formal maps in Kenya and Tanzania record pastoral resources from the perspective of pastoralists: for example livestock routes, pastoral water resources or different categories of pasture. Pastoral areas are often depicted as empty areas devoid of any signs of productive use. This makes them vulnerable to loss or fragmentation from other land use systems such as commercial agriculture, conservation or tourism. Compared to sedentary farming, the transient use of resources by pastoralists makes it hard for outsiders to identify specific land use strategies. It is far easier, and possibly politically more expedient, to identify and then map private land holdings using well-defined political boundaries than to recognise the diffuse and ever-changing usage of the commons.

Participatory mapping has long been used to capture the knowledge and perceptions of community groups. These maps are typically drawn on the ground using stones, bits of wood and other easily available material to depict key features such as schools, water points, forest areas, etc. (Rambaldi *et al*., 2006). Such processes produce perception maps, rich in local knowledge and reflecting community priorities. From the perspective of government planners, however, such maps are of limited use for planning. They lack accurate scales or coordinates – the characteristics essential for demarcating the location and extent of resources, and with which to develop byelaws for their protection and good management.

Combining community-drawn perception maps with digital mapping offers a number of benefits. Not only do the maps then contain a built in coordinate system that responds to a global reference grid, enabling their linkage to maps used in formal systems, but the coordinate system also provides a geographically precise basis from which to discuss natural resource management. The outputs of participatory mapping are therefore infinitely more useable and reusable. These benefits, however, need to be carefully balanced to avoid the risk of the process leading to highly dynamic pastoral resources being 'frozen' in time and space; or precise boundaries defined for resources that are inherently indistinct on the ground and highly variable, making the flexibility of rangeland resource misrepresented.

APPROPRIATE SCALE AND FOCUS

Pastoralists make use of resources that are spread over vast areas, and that vary in their productivity and value within and between years. Depending on the type of pastoral system, and the prevailing conditions with respect to pastures, security or market opportunities, pastoralists may travel considerable distances with their livestock to access pasture and water. Mapping pastoralism therefore requires attention be paid to a range of different scales - from the individual settlement-level scale for the planning of domestic water, to a wider ecosystem or landscape-scale for the planning of livestock mobility corridors between wet and dry season grazing areas. Conventional planning (and mapping) in the ASALs, particularly at local government level, usually occurs within specific administrative and/or political jurisdictions, such as a village or a district, and does not usually extend to capturing the full spatial extent of pastoral livelihood strategies, and movements that may cross numerous political and ecological boundaries.

The flexible nature of digital maps allows users to zoom in and work on specific areas, and then to zoom out to obtain a wider view of the data. This is invaluable when developing maps of pastoral resources and livelihood strategies that require a presentation of data and analysis at multiple scales. Currently, the maps produced for Kenya and Tanzania are constrained by political boundaries but it is possible to see cross-border issues emerging. For example, the water made available at the foot of Kilimanjaro has a sphere of influence covering a large portion of Amboseli National Park and many major cattle routes connect this area that crosses the Kenya – Tanzania border (see Figure 2).

Figure 2 Waterpoints at the foot of Kilimanjaro, Tanzania and livestock routes radiating northwards into Kenya.

POOLING LOCAL KNOWLEDGE ON TO A SINGLE PLATFORM

Capturing information into a digital platform allows several groups to contribute independently to the same collective map. This allows cumulative improvements to be made to the level of detail, and to the extent of its coverage, as well as crosschecking of the map. The digital platform allows different groups to add information concerning the areas they are particularly interested in and to easily comprehend one another's contributions. The fact that contributions can be made independently also facilitates the reconciliation of divergent interests and more informed dialogue.

PARTICIPATORY MAPPING – PROCESS AND ACTIVITIES

A systematic workflow for the specification, capture, validation and verification of information has been developed, evolved and tested in the County of Isiolo and the District of Longido (Figure 3) through work with community members, and local and national government representatives. The approaches in these Isiolo and Longido have varied slightly in their detail, so the workflow described here represents a generic review of the approach that allows the resulting data and mapping to meet quality standards.

Figure 3 High-level Summary of the Participatory GIS mapping and verification workflow developed and tested in Kenya and Tanzania.

Step 1. Community level meetings held to develop perception maps on the ground and/or on paper.

These meetings discussed natural resources and land management, and explored and listed the types of resources (features) they considered to be important and wanted to map (see legend Figure 2), as well as their reasons for doing so. Features included point locations (such as water points), linear features (e.g. migration routes) and areas (e.g. pasture areas and drought reserves). Participants used objects and marks on the ground to visually communicate their knowledge on key resources for livestock rearing (Figure 4).

These perception maps were then copied onto paper flipcharts and verified by local leaders and local government. Participants were selected by local actors to reflect a broad range of interest groups. In some cases, the perception maps were made directly on to paper flipcharts (Figure 5). These processes helped to introduce the mapping project and to identify the important issues and features to be included in the resource maps. The perception maps could be referred back to later to help guide the digital mapping process.

Figure 4 A small group of men exploring the distribution of key resources for livestock rearing in Longido, Tanzania. The perception map is built up on the ground using marks in the dust and stones.

Figure 5 Using paper flip charts to create a perception map in Kinna ward, Isiolo, Kenya

Step 2. Digital mapping is introduced.

Following a rapid three-dimensional (3D) exploration of the high-resolution satellite imagery in Google Earth (GE) to orientate participants, the features identified from the meetings were then located. GE was projected onto a large wall with the original paper perception maps hung next to them. Participants could navigate the imagery effectively and indicate key resources. Features identified in the digital mapping were digitised in Java Open Street Map Editor (JOSM)[5], a 2D Open Street Map data editing tool using agreed icons for point features, lines or polygons (Figure 6 and 7). This highly interactive process of geo-referencing local knowledge to a coordinate reference system allowed resource maps to be produced to any scale, and in real-time, with the community. This stage also allowed the first level of 'validation' of the data and discussion on the suitability of the products to meet the stakeholders' needs (community, local government and other external stakeholders).

The use of satellite imagery together with a terrain model for the participants to explore (Figure 6 & Figure 7) can be a stimulating, dynamic, non-linear and productive way of investigating local knowledge

[5] JOSM http://wiki.openstreetmap.org/wiki/JOSM Java Open Street Map Editor

on land and natural resources in a workshop setting. The projection of a large digital map onto a wall allows more intuitive and interactive approaches, leading to richer maps with more features, more detail, and the recognition of additional features outside the community boundaries. In Longido district 106 additional, un-mapped water points were identified and plotted during the data capture process. This increased detail requires some careful facilitation to ensure appropriate resource mapping however, as in this case the apparent abundance of water was misleading as further questioning revealed that at any given time a large proportion of them were not working. At the last workshop 28.5% of all of Longido's water points were reliant on rainwater recharge, had broken pumps, or had been disturbed by road building or elephants. The interactive mapping process gives instant feedback, providing immediate crosschecking of inputs within the group and a means to explore issues as they emerge.

Figure 6 Participants geo-referencing key natural resources in Longido, Tanzania.

Figure 7 Participants geo-referencing key natural resources in Isiolo, Kenya.

Figure 8 Overview of Longido District, Tanzania, showing pastoralist dynamics, natural resources and infrastructure

Figure 9 Oldonyiro Ward, Isiolo Count, Kenya, showing water point type and capacity.

Step 3 Qualitative and quantitative attributes describing the key resources are collected.

As participants put features onto the map they also described the specified characteristics or attributes of these features. Local knowledge is captured, for example with the attributes of the water resources the participants selected being described as including characteristics of quality, access, ownership seasonality as well as capacity. Relevant units for these attributes, such as whether water capacity should be measured in litres or in numbers of livestock supported, and for how long, were agreed with the participants. Similarly, plant species were recorded as characterising different grazing areas. Attribute information was also used to capture temporal and seasonal data, patterns of use of pastures, and water resources.

Updating this data on a regular basis will inherently add temporal and trend data to the spatial database, highlighting the need to structure the data systems well to manage time-based data and record updates. Different types of grazing areas are described according to the seasons they are used in, their physical features, and the species of plant that are usually present. In Isiolo different soil types were used to differentiate pasture types for example, chalk and black cotton that were clearly distinct in the satellite imagery. An inventory of over 200 plant species was given to further describe different grazing areas along with data on wildlife concentrations. These descriptions and data captured during the mapping process add considerable richness to the map and allow deeper analyses of the environmental systems they describe.

The attribute data was collected directly into the JOSM editor, as illustrated in Figure 10. One of the reasons for adopting the OpenStreetMap data model is that it did not impose a rigid GIS data structure on the community-led process. The approach allowed a flexible attribute structure to evolve through adding tags to the data, and allowed for example, the workshops in Longido District to take a different approach to that adopted in Isiolo County.

Figure 10 Illustration of the workflow and the data review and validation cycles developed in Isiolo, Kenya.

Figure 10 also highlights how two routes to create digital data were taken to meet the individual circumstances of the workshops. Where larger numbers of participants were involved it was easier to assign smaller groups to consider individual themes (e.g. water resources, pasture), marking on paper maps printed from the first phase of the workflow, and then bringing the data back together through back-office map digitisation. The end result of these processes is a centralised database that is accessible by many different software clients, of both the traditional desktop mode and also mobile and web-based. JOSM provides a rich-featured application that has been used to combine, edit and attribute spatial data and make subsequent edits within the community validation workshops. It can also be used to work offline (e.g. within workshops), and has proved a significant improvement to editing in QGIS[6]. Exports from JOSM to GeoJSON[7] can be used to theme data for display and analyse data in QGIS.

The data are transferred from JOSM to a central online database which maintains a full editing history, allowing a variety of tasks to be undertaken from the roll back of erroneous data entry to change analysis. Due to the popularity and widespread use of OpenStreetMap, the database is accessible by many clients making the data available to as wide an audience as possible.

Box 1 describes the vision for the management of the geospatial data resulting from the community validation workshops, but which would be subject to community and district, or county government, acceptance.

---

[6] http://www.qgis.org/ Open Source Geographic Information System (GIS) licensed under the GNU General Public License.
[7] GeoJSON http://www.geojson.org/ Open Source format for encoding geographic data structures

Protecting the investment in community mapping is important, as the information value will decline over time if the data are not updated. In developing the geospatial data from these mapping exercises there is a need to record the sources and processing within the information through metadata, especially if there is to be an effective updating strategy and use of data as a baseline for assessing change. Integration of imagery from satellite data (e.g. Landsat TM) and aerial imagery using the Google Earth platform and the Image Overlay tool - was used in Longido to drape image data over the 3-D terrain. Integration of data derived from image processing from agro-meteorological monitoring and early warning was also used within the workshop; images of seasonal productivity of pasture as described by monthly Normalised Difference Vegetation Index (NDVI) images[8]. Figure 11 show the use of NDVI data derived from medium resolution (250m) Moderate Resolution Imaging Spectroradiometer (MODIS) satellite images, that represents the extent of vegetation across the wet (May 3 2014) and dry (July 3 2014) seasons in Kenyan ASAL. The figures are a ratio from 0 -1, where the greener the image the greater the vegetation cover, which helps communities identify and describe the extent of pasture blocks.

Figure 11 Normalised Difference Vegetation Index (NDVI) images integrated into the mapping environment: a) wet season, May 2014 and (b) dry season, July 2014. (*Source: U.S. Geological Survey*).

Box 1 OpenStreetMap, a basis for co-ordination of the ASAL pastoralist knowledge

Integrating multiple community datasets to offer a consistent view of resources presents a considerable challenge, given the parallel desire to engender ownership by encouraging local choice of the relevant features and attributes, naming conventions etc. Behind the technical workflow described above has been longer-term thinking about sustainability and future data management approaches. This thinking has been based on the concept of the OpenStreetMap (OSM) model, which provides a highly flexible, loosely structured dataset, based on 'tags' that describe the features (pastures, water points etc.) and their attributes. The strengths of OSM for managing the coordinated data are in its ability to store data within the OSM server (cloud) that is available to all. Free access may not be amenable for some of the data, or for some stakeholders, and the relative merits and drawbacks need to be debated with the participants. The OSM data licence enables

[8] Normalised Difference Vegetation Index (NDVI) a ratio derived from multi-spectral satellite image interpretation provides an indicator of the productivity of vegetation.

sharing, reuse and modifications; but although this model is widely used, it is a licensing model, and therefore needs debate and awareness of the implications in just the same way as if a more restrictive or commercial licensing approach were adopted. A number of issues need to be considered before disseminating information. For example, in Longido District the Ministry of Land supplied beacon data and physical marker locations that mark the village confines. This official data has been used to help set the community mapping in the context of the legally defined boundaries. It helps to ensure that the community data has validity for quality and consistency when integrated with other information – a target that is rarely met in earlier PGIS programmes. The beacon locations may not be appropriate to publish under the OSM licence however. The approaches have adopted the Open Source OSM software stack, subject to community and local government agreements. All editing is performed in an OSM Editor (JOSM), a specialised yet intuitive editing tool. JOSM is ideally suited for managing the existing mapping data and creating a centralised database. The database will be updated with new data as it arrives from the workshops using various tools, notably the JOSM editor (that can work online or offline). Existing data can be validated and edited. Another option is also to leverage the data through export to other formats (e.g. bespoke PDF maps, online maps) and analysis (e.g. change analysis). Desktop QGIS is still an appropriate tool for map-making and analysis and has been used to develop paper-based Atlases which are now completed for Isiolo data, and are underway in Longido.

Steps 4-6: Data verification cycles integrated into the mapping process to capture community feedback and verify the records in the geospatial data and their attribute values against the specification.

This stage explored the use of other data to assist with verification, for example multi-temporal satellite-derived data such as the Normalised Difference Vegetation Index (NDVI) maps of agricultural and pasture production. Workshops included regular feedback sessions to return the data to those who provided it, and to thoroughly crosscheck the results pooled from different groups. These regular cycles of contact and learning also helped to build trust, and encourage the sharing of information on sensitive data, such as sacred sites and gemstone locations. Revision cycles allow for the community to continue upgrading the quality of the data – for example the record of geo-referenced local place names was updated with local names, alternate names and multi-lingual entries throughout the meetings.

Verification within the context of participatory GIS involves converting from a paper-based, topological representation to geo-referenced digital data. Validation and verification includes both the topographic and classificatory accuracy of features and their attributes, and the appropriateness of the information. The mapping process also enables testing of the validity of the perceptual nature of the local knowledge and the partial nature of mental maps. The staged workflow, with feedback quality loops, helps to standardise the process, whilst community workshops help to resolve gaps in knowledge and integrating of imagery illustrates where information density is low.

Despite the extensive local knowledge the viewpoints of communities and groups within communities are always likely to differ, and capturing this variation within the context of the digital mapping may be a relevant target for explaining variations and priorities. In this regard there is also the scope for capturing gender and generation-specific views of the landscape. Validation, and the representativeness of the information, depends to an extent on capturing these differing perspectives.

The interactive nature of capturing information against the projected imagery allowed participants to see the map emerging from their individual contributions. This allowed instantaneous crosschecking throughout the collection of data. It was also helpful to use the measuring tool, a flexible scale bar that can measure distances from the image in kilometres, and particularly when zooming in and out to keep participants orientated and allow better crosschecking within each group. Measuring distances, for example to triangulate the location of a new point in relation to other known points, or to measure the breadth of a grazing area, helped generate accurate data. Participants also often became interested in checking the accuracy of their knowledge against the ruler tool, and seemed to enjoy verifying their knowledge of distance and direction using the satellite imagery.

The pastoralist groups participating were male-dominated, especially when discussing issues of long distance herding and territory. Except for discussions on the location and attribute of domestic water sources and households, men's contributions were overriding, reflecting the organisation of the livelihood and herding. But in workshops that were facilitated or attended by powerful women it was observed that women contributed more. Collecting data separately for men and women's groups is important, with the use of a digital platform to overlay and share these different views later. This finding conforms to other mapping exercises, where men and women often produce quite different maps when working separately.

Step 7: Field validation

Field validation was carried out where the verification stages highlighted gaps in information, for example details where on the ground were masked by cloud cover on the satellite imagery, or where there was uncertainty over classifications or attributes. Verification consisted of using GPS markers to target field visits to check the uncertainties and update the maps.

A key target for the participatory workflow approach has been to focus on areas where community workshops agree that there is uncertainty - uncertainty that can be effectively indicated in the mapping. Ground truthing can thus become more targeted and thereby cost-effective. Increasing access to GNSS/GPS has enabled the use of smartphones and back office synchronisation, whilst web 2.0 knowledge sharing applications offer the opportunity to distribute this verification further and integrate field data (see Box 2).

> Box 2- Using Mobile Phones for Participatory Data Collection
>
> In one ward in Isiolo County participants were able to improve their participation and the quality of data collection. Several features important to livelihoods were found to be more recent than the viewed satellite imagery. Participants were able to map these new features precisely and quickly by visiting them on a motorbike, and obtaining coordinates with GPRS enabled mobile phones. These coordinates were then entered into the computer so the features could be displayed in their accurate locations. Whilst not efficient for mapping larger areas, the approach is useful for point-based features (such as water points) and also illustrated the strength of local knowledge and capacity for verification and local ground-truthing. When the coordinates were entered manually the points of interest did not jump far from their previously estimated positions. The steady uptake of this kind of technology and the possibilities it offers could have exciting implications for ownership, monitoring changes and building more robust, geometrically-accurate 'ground–truthed' maps.

It is worth noting that this whole cycle of steps is fairly idealised, and that in reality it is useful to remain flexible; for example collecting GPS marks for key features prior to feedback sessions and using feedback sessions to gather and standardise attribute data. Having achieved verified geospatial data the layers can be integrated within a GIS for presentation and visualisation, and the database store is updated to maintain the record.

The technologies selected to support this participatory GIS have been based on open source software components. The selection criteria for open source tools was that they freely accessible, without restrictive licenses and relatively simple to use whilst being rich in functionality; thus they may be particularly suitable for cost-effective implementation in local government applications.   These have been explicitly experimental and have evolved through the programme. During the preparatory stages a series of platforms and data management approaches have been tested in either or both of the study areas (in Longido - the web portal, in Isiolo - paper mapping, satellite imagery, and crowd sourcing as part of validation and updating). The selection of approaches however has had a longer term 'vision' in mind for a coordinated dataset, drawn together from multiple community mapping workshops.

The displaying of the data back to the participants used Google Earth, the Google digital earth viewer. This virtual globe application allows online exploration of imagery (satellite or aerial coverage) in a 3-dimensional view, allowing the powerful navigation of the data against the terrain, and resources to be identified in a community context. This has been used alongside the paper-based mental maps generated in the first step of the workflow.

PRESENTATION AND VISUALISATIONS

Data and information portals are not new within this PGIS context (Pfieffer et al 2008) but there are few examples of effective end-to-end development from participatory mapping. At this stage the pastoralist portal functionality is still limited, but the progress made demonstrates the themes of mapping generation and the potential route for presenting and distributing information to policy makers.

The data portal has been developed on Leaflet open source web mapping technologies. Leaflet is an open-source JavaScript library of interactive mapping for online and mobile technologies, based on HTML5 and CSS3 languages for content and styling of web applications. The application provides a rich library of functions for map, interaction control and navigation, only partially implemented within this phase. The information portal supports 'scale-visibility' of the community map layers, using the styles defined by the mapping participants, and map scales at which information is depicted using maximum and minimum view scales. Symbolization and legends for the information have been developed specifically for these maps with the community. Underlying topographic detail is rendered using the OSM cartographic model (Mapnik[9]).

Cartographic representation can be manipulated within the desktop GIS QGIS desktop environment, but for the portal – that potentially provides access and management across a wider region - some levels of standardization is required. Again the OSM model is used for managing the cartographic elements within

---

[9] Mapnik http://mapnik.org/ is a library of tools for rendering in mapping applications.

the open source model – where the feature styles are OS community maintained within CartoCSS. There are some challenges to this approach within the online environment where scalable symbols are harder to create and attribute-based styles are needed in order to display characteristics of features.

Figure 12 compares the impressive level of detail from the community data on the online portal, compared to that within the current OSM equivalent, for the area between Kinna and Gabra Tula in Isiolo County. Significant additional topographic and agricultural detail has been collected and integrated into a standard platform for the district. Current levels of detail within OSM data belie the diversity and complexity of the rangelands, and the community view portrayed in the community portal. This difference illustrates the often-held appreciation of dryland areas outside the pastoralist community and the challenge of communicating spatial planning issues when little is known about the environment, locations and features. This PGIS mapping has been run over 4% of the country (as at January 2014), representing an impressive coverage and highly cost-effective method.

Figure 12 Contrast in the mapped features between the Community Resource Map (a) and existing Open Street Map (b) data for drylands between Kinna and Garba Tula, Isiolo, Kenya.

A further presentational exploration within the preparatory phase published a digital fly-through online video for Longido using Google Earth Pro (Figure 13). The video was created with a community representative in order to illustrate the results of the mapping at the community workshop. 'Placemarkers' were captured within Google Earth to create an animated tour that was narrated to provide context to the extensive areas, and the cross-border requirements of the pastoralist community. Local names and natural resource features were used to label the animation based on the feature layer gazetteer captured within the community workshops.

Figure 13 Online video of Isiolo community mapping of pastoralist resources (*YouTube*)**DATA**

MANAGEMENT AND SUSTAINABILITY

Despite many past PGIS mapping programmes in both countries there is little mapping standardisation, maintenance or updating of information with the consequence that information is lost or becomes outdated. Data that does exist are often not effectively described; or the provenance, ownership and licencing has not been established, which diminishes their capacity for reuse and reduces credibility of the information.

The data management within these programmes has adopted open source technologies to reduce barriers to uptake at county and district levels: the software is free and a wider community of developers supports its update. The data and information collected, and the capacity created as part of the programme, will contribute to the programmes' sustainability and the potential for the data to be used for subsequent programmes and other contexts. To realise these benefits the preparatory stage has evaluated data management issues.

The prototype portal was developed within the Isiolo context and has initially been built around the ODC Open Database License[10] that allows the map data to be shared, copied and adapted - subject to attribution, 'share-alike' and 'keep open'. Similarly, the imagery used within the portal has adopted the CC-BY-SA,[11] with share, adapt and commercialization rights subject to attribution and share-alike conditions. The wider access to these datasets needs further consultation with all local actors. Current hosting of the portal is within GeoData Institute, although hosting in country is pending consultation.

Currently, the pastoralist community's data are not accessible through the OSM database, as licensing and control of potentially sensitive data (protected and sacred areas) also requires further review and discussion within community workshops. Presently, within this phase, there is no metadata (data about the data) associated with the data which would be needed prior to distribution.

SUCCESSES, CHALLENGES AND LESSONS

The overall objective of the preparatory Kenyan and Tanzanian phase of community mapping was to strengthen the capacity for local pastoralist knowledge to influence land management decisions and land use policies developed by government planners, as well as targeting adaptation actions. Presenting information alone will not necessarily result in positive attitudes to pastoralism, or decision behaviour change; but it is seen as a valuable step in a sequence of advocacy for pastoralism as a sustainable land management strategy in the ASALs, particularly in the context of climate change.

Mapping is not the end game. If the goal is to effectively represent and interface the pastoralists' local knowledge to decision makers, the challenges start at the specification of the features and attributes, and continue through the data management, presentation, visualisation approaches and policies for information access; and right through to participation in planning on the basis of the map's information. This requires consideration of:

---

[10] http://opendatacommons.org/licenses/odbl/summary/

[11] http://creativecommons.org/licenses/by-sa/3.0/

i) The extensive nature of customary management that requires local knowledge, contribution from multiple community territories across the wider ASAL region, differing perspectives (e.g. alternate land uses, wildlife, tourism) and the requirements for scalable data.

ii) How to achieve the validated, verified data to offer authoritative pastoralism information.

iii) The approaches to present, visualise and analyse data and information, and accord it due weight in the context of spatial planning within competing land uses.

iv) The policies and procedures for access, management and maintenance of information to ensure sustainability and continued relevance.

In small workshop settings the community mapping has allowed local knowledge to be efficiently and effectively captured so it can be precisely and useably described in accurate digital maps. Participants at these workshops were able to navigate the imagery with ease, leading to the collection of data that reflected their priorities. The use of virtual earth applications, with the ability to take an oblique view, helped participants to orientate themselves. Once this 'we are here' point had been established, participants rapidly oriented themselves and began to take control of the interactive exploration of the study area.

Most groups started by adding major landmarks before fleshing out the details in-between; some groups used mountains, some rivers and some roads as reference points for doing this. Other groups added all levels of detail methodically, moving away from the starting point - the location of the workshop. Allowing participants to drive exploration of the areas was very important but it meant slightly different mapping styles emerged as a result. Being able to document local knowledge in small workshop settings also made digital map-making cheaper and more efficient, reducing the need to invest in fieldwork. Iterative cycles of the mapping process and exploration of satellite imagery encouraged deeper consultation of local knowledge, generating a fuller description of key resources and usage patterns.

The management of the process, by which the images are projected and manipulated, is crucial to the success of the mapping exercises and a great deal depends on the quality of the facilitation. As with all participatory methods, the tools are not as important as the approach and principles being followed in the facilitation. If the tools are designed with the process in mind, for example the collaborative recording of attributes allowing simultaneous update to the feature on screen, the interaction with the participants is that much more natural. Digital mapping is just a recent addition to participatory processes that are themselves something of a paradox: a facilitator who has control of a process wanting to hand it over to other people.

VALIDATION, VERIFICATION AND CERTIFICATION

A key lesson from the application of the participatory mapping has been the importance of the validation process and learning through the adoption of the workflow. The value here is that local communities define important elements (features) and their attributes and measures; and they also validate and verify the results to further enhance the authority and reliance that can be placed on the information (Pretty 1993).

The stages of returning the information to the community, whilst trading on their time, remains cost effective in terms of the extent of the area covered, the quality of the data achieved and the resulting degree of ownership of the information. The cycle of consulting local knowledge, processing it (within the course of the workshop) and then re-presenting the data back built up trust, as well as richer maps. Having gone through three cycles of collecting mapping data and feeding back the results in Longido, a piece of paper describing a sacred site and two important gemstone seams was given to the facilitators. This incident highlights the importance of returning data to the groups that provided it, and crosschecking the digitisation process both within and between groups.

Digital maps can demonstrate the robustness of community perceptions. This can be achieved by directly measuring the accuracy of perceptions against the imagery, by ground truthing with handheld GPS, and also by simply comparing the paper maps from early in the mapping process with the digital maps they later produced (Image 8). This, along with the detailed attributes describing features of the map, can be used as evidence of how highly developed and necessary this knowledge is for harnessing the potential of the drylands. Maps made in this way are very swiftly and accurately produced in a manner that is compatible with other data and spatial planning requirements (particularly with land use categories in which local people and institutions had limited knowledge and involvement: tourism, hunting, conservation enclosures and rare minerals). This permits the overlaying of different maps and potentially, where appropriate, the formation of arguments that reconcile mainstream planning with customary land use reasoning and priorities (Figure 14).

Figure 14 Comparison of paper perception maps and geo-referenced digital online geospatial datasets shows the accuracy of local knowledge in terms of distance and direction.

PRESENTATION, VISUALISATION AND USE

Presenting the data over a different base-map with clear icons helped participants to reinterpret their maps and provide amendments and additions. Some groups preferred a base-map made from the original satellite image, but in black and white to allow the data in colour to stand out, others preferred solely using elevation data with a directional hill-shading effect to highlight the topographical relief of familiar features.   For community contributed data to support decision making it needs to be made available and presented in a way that can support the decision making process. One key output of the PGIS mapping that may be easily integrated into national systems is the gazetteer. This provides a common framework for naming features (including customary names and multi-lingual names) that can support local mapping outputs and communication. Developing data models that allow multi-lingual presentation, multiple symbolisation and aggregations, will permit outputs to be tailored to different user communities.

Some groups were also vocal on how they wanted the maps to look, but fortunately there were no conflicting opinions and it was possible to use the styles of the groups that were most vocal on this issue i.e. blue for livestock routes, red for arable farming areas and so on.

SETTING POLICIES

The digital map is a 'live' dataset that can be updated over time with improvements and additions. Participatory mapping entails considerable investment - from community participants, facilitators and technical specialists - yet the information is rarely accorded significant asset value. Lessons from past mapping programmes are that, without mapping standardisation, maintenance and updating, these values cannot be fully realised or maintained, resulting in low sustainability. This emphasises the need for participatory programmes to manage data effectively, and update and maintain the resource.

The emergence of national spatial data infrastructure policies (Kenya SDI, (Une et.al .2003), Tanzania SDI (Lugoe and Yanda 2007)) is starting to recognise the value of digital datasets and accord information its importance as part of national 'infrastructure' - recognising spatial data in the public domain as enhancing 'transparency and participatory governance'. SDI essentially sets policies, standards and technologies, and considers human capacity and related activities (such as awareness and training) for geospatial data sharing. Approaches to embedding community-derived mapping into SDI policies will require further community and governance debate, but may offer a model for data access and management (Figure 15).

Figure 15 Participatory mapping integration into a spatial data infrastructure for management and distribution of information

Making the maps and data accessible for widespread use is becoming a critical issue. Currently there is no mechanism for distribution of the data, for which the pilot web application was trailed in Isiolo; although the web data portal has data view services, it does not yet support download services or outputs. Initial discussions on the policy for distribution need to extend to set distribution, use and re-use rules that are recorded within metadata. This is essentially an issue for community and cross-community consultation, and needs consideration of how the options affect the value and influence that the data has in strengthening advocacy.

In principle, an open data model has been proposed for the data derived from participatory maps, based on the Open StreetMap platform. The advantages of the OSM model, with data in cloud storage, are the provision of distribution, download and view services at low to no maintenance cost. Such an open model may start to undermine the coherence of the information contributed by the community however, and the challenge will be to ensure consistent and currency of coverage, potentially resulting in loss of the values of the workflow in setting the quality certification. There are also some potential limitations for OSM data models and licensing that may not work for culturally sensitive information. Such questions need to be framed around whom does it benefit and for whom would it produce a dis-benefit if the information were open? Despite benefits in terms of flexibility for some users it has limitations, and may start to disenfranchise groups without computing access and tie the facilitators to a reliance on technologies. Similarly, legal advice is needed to support the use of geospatial data for some uses, such as drafting byelaws.

LOOKING FORWARD

The community mapping work in Longido and Isiolo has successfully illustrated the value of the workflow and the integration of terrain data, 3D visualisations and satellite imagery and analysis in improving the quality, consistency and authority of the resulting output data and maps. By adopting early community-led specification and attribution standards alongside common symbolisation, it was possible for the community to build and validate rich data with minimal facilitation. This provided robust, defensible and authoritative wide-area geospatial information that articulates their local knowledge to government policy makers and planners. It takes community level data to a point where it can potentially contribute alongside spatial planning, boundary setting and framing of byelaws and analysis. It also introduces a new dimension to the relationship with government and policy makers in sharing understanding and insight into the issues affecting pastoralist livelihoods.

Use of relatively new technologies, particularly in this context (using internet technologies, digital earth and data management), has helped facilitate dialogue between participants. The approach presented no barriers to understanding, enabling capture and representation of community insight. The multi-level process, with validation and verification workshops, supported the systematic collation of both generalised and detailed data within a common platform, and allowed distinctive perspectives to be viewed side-by-side (seasonal difference, gender differences in mobility or perceptions). The cycles of verification, backed where uncertainty existed with field verifications, including the use of GPS tagged mobile information, providing a strong basis for continued maintenance and cost-effective update by the community.

Participatory GIS allows integration with data from other communities and other sources, and also permits effective community ownership and retention of data for monitoring and evaluation and information exchange. Such approaches illustrate the capacity for communities and local government to promote evidence-led policy development and planning, and offer significant potential for future integration of complex, multivariate information - and the development of decision support systems.

Mapping using digital technology in conjunction with local knowledge is still relatively new in East Africa, but is showing early promise not only from a technical perspective (e.g. accurate, efficient, cheap and transferrable), but also as a tool to empower communities and bridge communication gaps between citizens and their government. The project has highlighted three areas for focus and future development:

1. Strengthen community participation in resource assessment and mapping.

- Extend the geographic coverage of community mapping.

Work is ongoing in Longido and Isiolo in which the maps described in this paper will be used to directly support decision-making on public good type investments to build local adaptive capacity for climate variability and change. Plans are being finalized to extend and up-scale the work to neighbouring Counties and Districts in Kenya and Tanzania respectively. As the size of the area mapped increases towards the ecosystem scale, a more comprehensive overview of pastoral dynamics, cross-border effects and natural resources and ecosystem service distributions will emerge, resulting in an increasingly powerful tool.

- Validation and verification of information.

Effective approaches trialled within this programme offer opportunities for wider use, for example techniques such as crowd-sourcing data (Box 2) to develop a community of users and contributors to field-based validation.

- Creation of paper-based products

Despite the workflow and programme focusing on digital geospatial data, there is a call for paper based ‘Atlas’ outputs to ensure that a wider audience can share the information; especially where hardware, software and even electricity cannot be assured. Whilst recognising the flexibility of digital data within the preparatory phase, paper map outputs have supported digital workflows, and an Atlas is proposed to maintain the access to a wider audience.

2. Improved information management.

To achieve better handover, uptake of ownership, and secure on-going monitoring and update of changes, it is necessary to further explore how to incorporate the spatial data and attributes into interactive mapping tools to support adaptive management and decision-making.

The technical models and approaches retain the flexibility to represent data at the community level as well as integrate data at ASAL levels. Issues remain though, specifically the need to determine longer-term management, a systems design, implementation to support these objectives and agreement on an access policy that support the objective of 'information to support advocacy'. Training and embedding in the community is needed to secure the sustainability of these approaches.

- Centralised information portal

  Development of a centralised information management portal, and the arrangements for licencing and release of data, require further elaboration with the community to effectively and efficiently support data and information sharing. Such extension of the portal also allows the potential for online collaboration in data verification and update.

- Support for the adoption of Open Source GIS mapping tools

  Some challenges stem from the need for a handover of digital technology. Uptake of Open Source technologies and the spread of GPRS-enabled mobile phones greatly support this process. Recent establishment of open data principles and the integration of data within a Spatial Data Infrastructure framework will further strengthen these processes, although it requires further development and building of capacity at county decision-maker levels to fully capitalise on this information.

- Strengthen the harmonisation of data

  The communications gap between pastoralists, other stakeholder groups, and managers can be partly bridged using accredited and harmonised geospatial data, and maps to connect local knowledge with other geospatial data and information. The extension of mapping brings with it issues of standardisation, integration, generalisation and simplification, as well as crucial data management issues that need to be resolved between different community maps and with other geospatial sources.

- Develop metadata to describe the data

A key component of thinking of the geospatial data as a ‘resource’ may be to treat it as part of the national infrastructure – the spatial data infrastructure (SDI). In order for this to be formalised, ‘metadata’ - data describing the data and its quality, provenance and use - is an essential element. This also supports the development of maintenance and update strategies.

3. Build the capacity to use and maintain the information.

- Develop local / regional support mechanisms for information management and updating

Handover of information and the process for maintenance requires enhanced capacity within the community and institutions to make effective use of the information.

- Build awareness of the information resource at national levels

The capacity and will of government to accommodate pastoralist knowledge and reasoning in the mediation of land management issues will determine the success of landscape scale rangelands management in the long term. Increased awareness and establishing confidence in the quality of the data, and its potential exchange with Government and national institutions, is needed.

- Build a firm legal base for utilisation of the information

The strength in the data lies in being able to apply it to support the land management issues. Legal advice is being sought on how to license and use maps to support bylaws protecting key resources, and preserve the mobility required to access them.

Mapping by itself does not infer or affect pastoral community group resilience. Rather it is a tool for communicating local knowledge that, when it is given room to be applied, can engender resilience in pastoralist communities. It is hoped that the upshots of mapping local knowledge can be brought to bear on the activities of other rangeland users who would otherwise displace and disregard the dynamics of pastoral land use.

The production of a map however is still several steps away from its use by politicians to mediate competition over land and resource access. Validation of maps by community groups and local government, empowering local government and customary institutions to make use of them to form appropriate planning and public good type investments, seeking legal advice and legal action over gazzettements to protect key areas, and generating will at the national level not to override local governance, are all still required for mapping to have impacts on livelihoods on the ground.

REFERENCES

Behnke R. (2006) Review of the literature on pastoral economics and marketing: The Horn of Africa and Southern Africa, IUCN EARO, Nairobi.

Behnke R. (2008) The economic contribution of pastoralism: Case studies from the Horn of Africa and Southern Africa. *Nomadic Peoples* 12(1): 45–79.

Behnke R. (2010) The Contribution of Livestock to the Economies of IGAD Member States. Study findings, application of the methodology in Ethiopia and recommendations for further work, IGAD LPI Working Paper No. 02 - 10, Djibouti.

Behnke, R., Scoones, I. and Kerven, C. (eds.) (1993) Range ecology at disequilibrium: New models of natural variability and pastoral adaptation in African Savannas. London: Overseas Development Institute.

Behnke, R. and Kerven, C (2011) Replacing pastoralism with irrigated agriculture in the Awash Valley, North-Eastern Ethiopia: Counting the costs. Paper presented at the International Conference on Future of Pastoralism 21 --- 23 March 2011, organised by the Future Agriculture Consortium at the Institute of Development Studies, University of Sussex and the Feinstein International Center of Tufts University.

Breman, H. and De Wit, C.T. (1983) Rangeland productivity and exploitation in the Sahel. *Science, New Series* 221(4618): 1341–1347.

Burnes, B. (2004) Kurt Lewin and the planned approach to change: A re-appraisal. *Journal of Management Studies* 41 (6) pp977-1002.

Catley, A, Lind, J. and Scoones, I. (eds). (2012) Pastoralism and development in Africa: Dynamics Change at the Margins. London, Routledge and Earthscan pp295.

Chambers, R. (1994) The origins and practice if participatory rural appraisal. *World Development*. 22, 7 pp953-969.

Dunn, C. (2007) Participatory GIS – a people's GIS? *Progress in Human Geography*. 31, 616-637.

Fishbein, M., & Ajzen, I. (1975). Belief, Attitude, Intention, and Behaviour: An Introduction to Theory and Research. Reading, MA: Addison-Wesley.

Galvin, K., Reid, R., Behnke, R. & Hobbs, N. (2008) Fragmentation in Semi-Arid and Arid Landscapes. Consequences for human and natural systems. Springer, The Netherlands.

Hatfield R. and Davies J. (eds.) (2007) Global review of the economics of pastoralism, WISP and IUCN, Nairobi.

Hesse, C. & MacGregor, J. (2006) Pastoralism: drylands' invisible asset? IIED Issue Paper 142.

IIED and SOS Sahel (2009) Modern and mobile: the future of livestock production in Africa's drylands. IIED and SOS Sahel, UK.

Keeley & Scoones, I. (2000) Understanding environmental policy processes: a review. IDS working paper, Institute of Development Studies, University of Sussex.

Krätli S. (2007) Cows who choose domestication. Generation and management of domestic animal diversity by WoDaaBe pastoralists (Niger), PhD thesis, Institute of Development Studies, University of Sussex, Brighton, United Kingdom.

Krätli, S and Schareika, N (2010): Living off uncertainty: the intelligent animal production of drylands pastoralists *European Journal of Development Research*, Vol 22, 5, 605-622]

Krätli S., Hülsebusch C., Brooks., S. and Kaufmann., B. 2013. Pastoralism: A critical asset for food security under global climate change. *Animal Frontiers* 2(5): 42-50.

Krätli, S. (2014) If Not Counted Does Not Count? A programmatic reflection on methodology options and gaps in Total Economic Valuation studies of pastoral systems. IIED (in print).

Krätli, S. & Enson, S.J. (2013) A review of global public policy narratives on the drylands. Issue Paper, IIED, London.

Leach, M. and Mearns, R. (eds) (1996) The lie of the land: challenging received wisdom on the African environment. Heinemann.

Lugoe, F. N. and Yanda, P. (2007) The national spatial data infrastructure (NSDI) policy proposal for Tanzania.

Niamir-Fuller, M. (ed.) (1999) Managing mobility in African drylands. The legitimisation of transhumance, IT Publications, London.

Pfeiffer, C. Glaser, S., Vencastesan, J, Schillermann-Kraus, E., Drescher, A. and Glaser, R. (2008) Facilitating participatory multi-level decision making using interactive mental maps. *Geospatial Health* 3. pp103-112.

Pretty, J. (1993) Participatory inquiry and agricultural research. IIED, London.

Rambaldi, G., R. Chambers, M. McCall and J. Fox (2006). 'Practical ethics for PGIS practitioners, facilitators, technology intermediaries and researchers.' In G. Rambaldi, J. Corbett, R. Olson, M. McCall, J. Muchemi, P.K. Kyem, D. Weiner and R. Chambers (Eds). *Participatory Learning and Action 54 Mapping for Change: practice, technologies and communications*. IIED: London. Online: www.planotes.org/pla_backissues/54.html

Une, H., Nyapola, H., Mbaria, C. and Maruyama, H. (2003) Towards the establishment of Kenya national spatial data infrastructure Proceedings of the 21st International Cartographic Conference (ICC), South Africa 2003.

Wilson, R. T. and S. E. Clarke (1976) Studies on the livestock of Southern Darfur, Sudan: II. Production traits in cattle. *Trop. Anim. Health Prod*. 8:47–51.

FIGURES

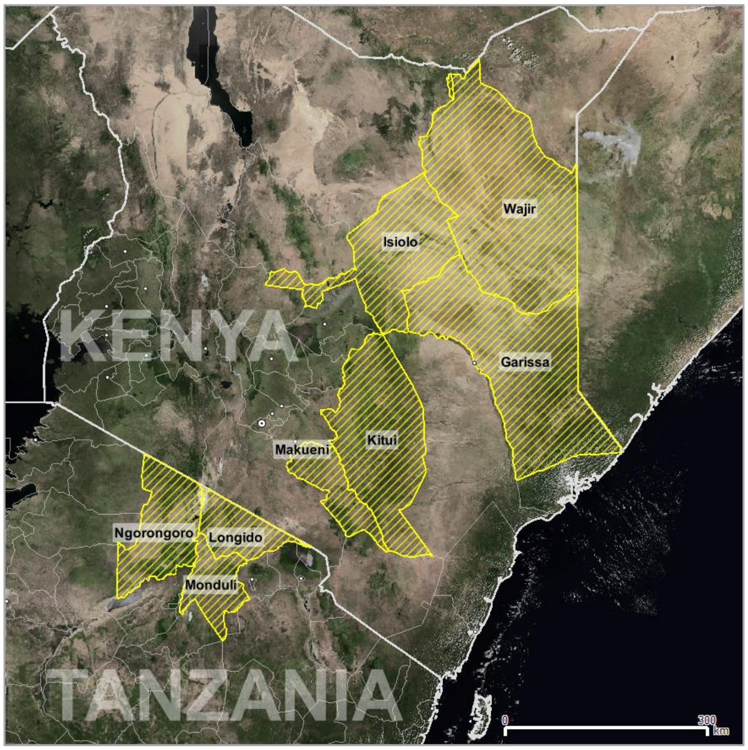

Figure 1 Location of ASAL participatory mapping programme

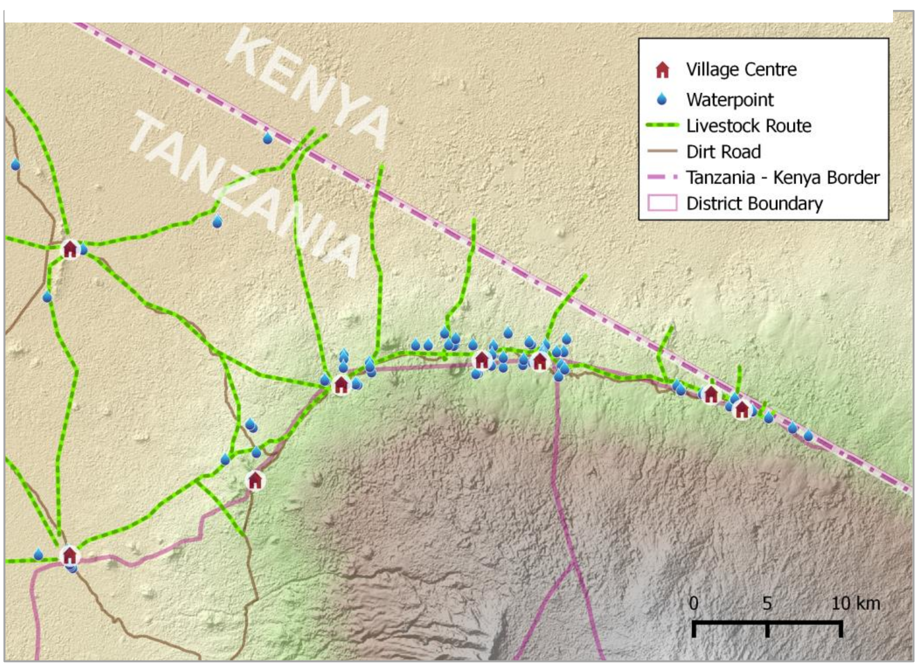

Figure 2 Waterpoints at the foot of Kilimanjaro, Tanzania and livestock routes radiating northwards into Kenya.

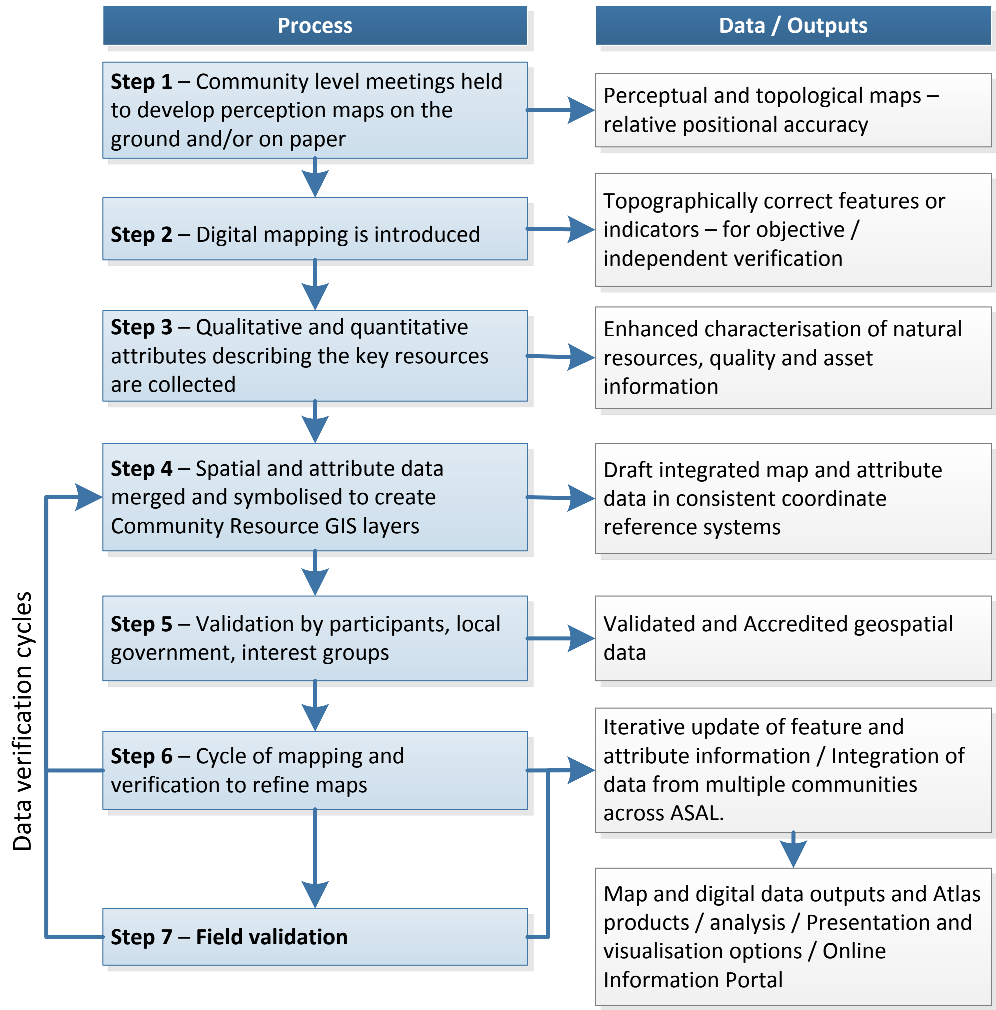

Figure 3 High-level Summary of the Participatory GIS mapping and verification workflow developed and tested in Kenya and Tanzania.

Figure 4 A small group of men exploring the distribution of key resources for livestock rearing in Longido, Tanzania. The perception map is built up on the ground using marks in the dust and stones.

Figure 5 Using paper flip charts to create a perception map in Kinna ward, Isiolo, Kenya

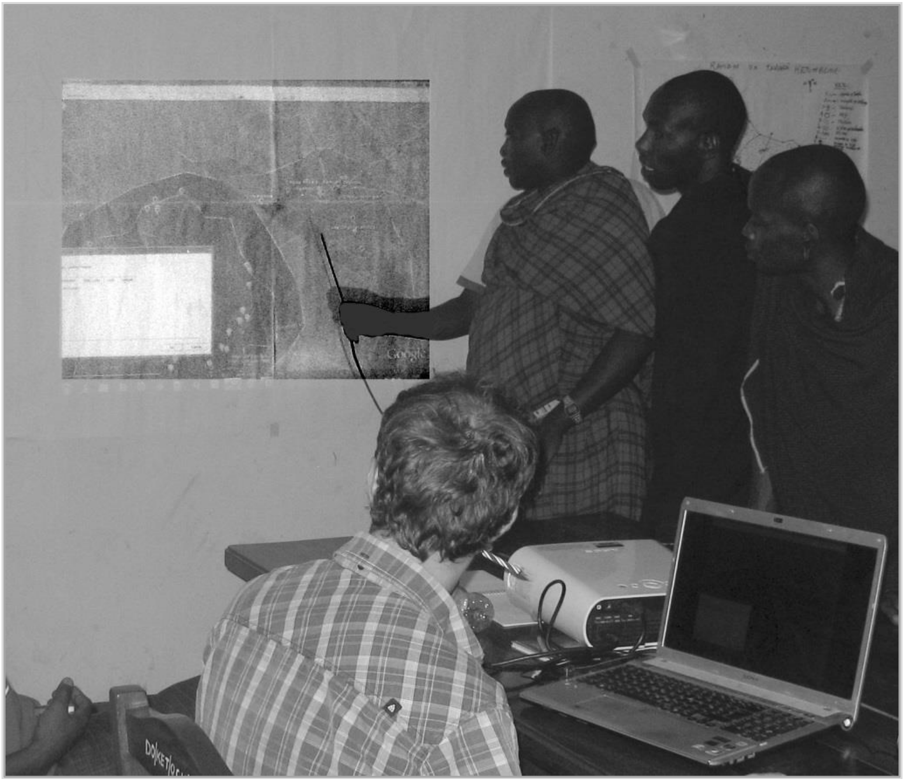

Figure 6 Participants geo-referencing key natural resources in Longido, Tanzania.

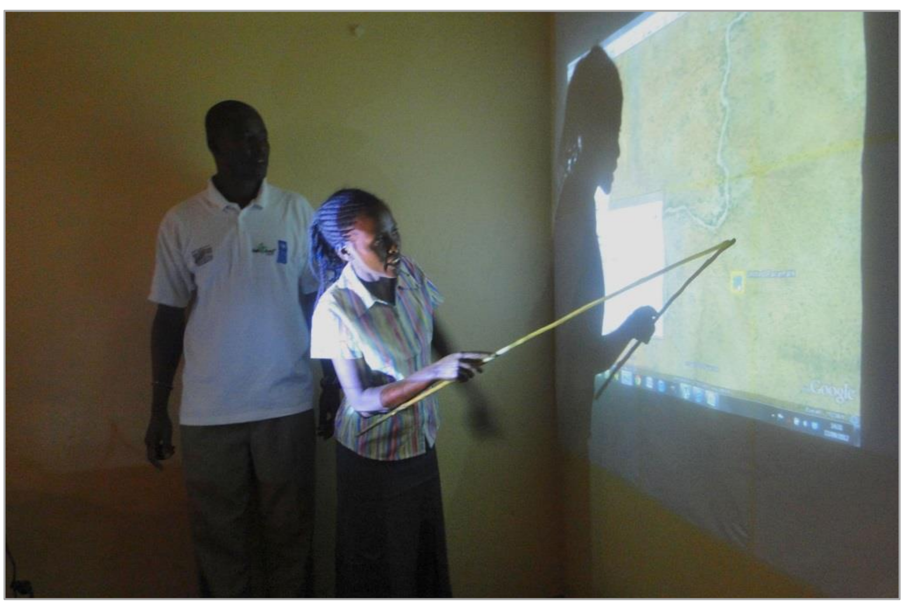

Figure 7 Participants geo-referencing key natural resources in Isiolo, Kenya.

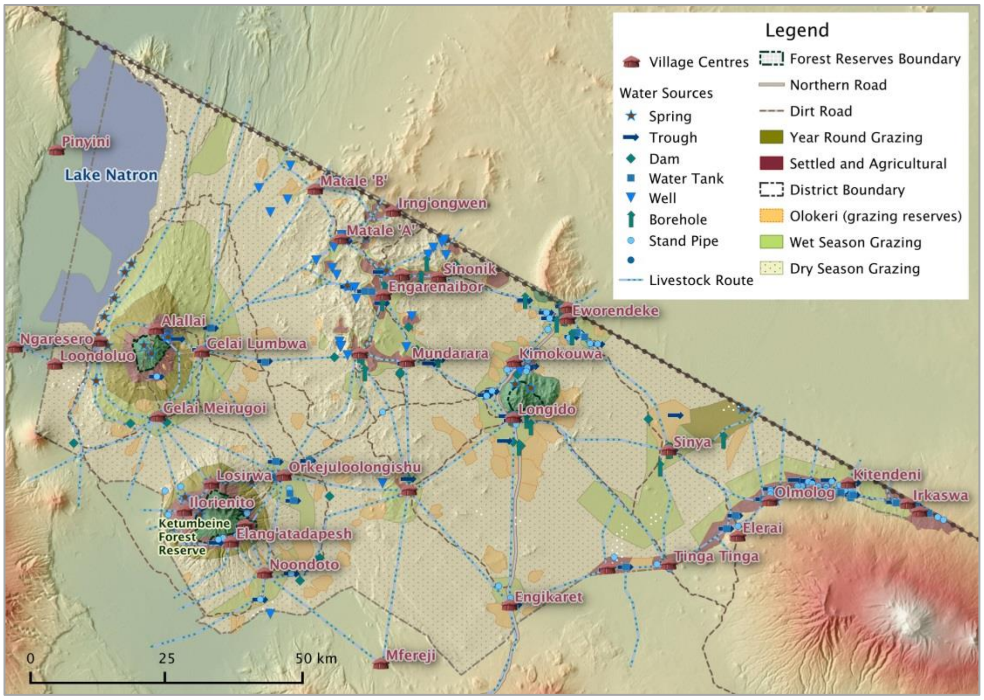

Figure 8 Overview of Longido District, Tanzania, showing pastoralist dynamics, natural resources and infrastructure

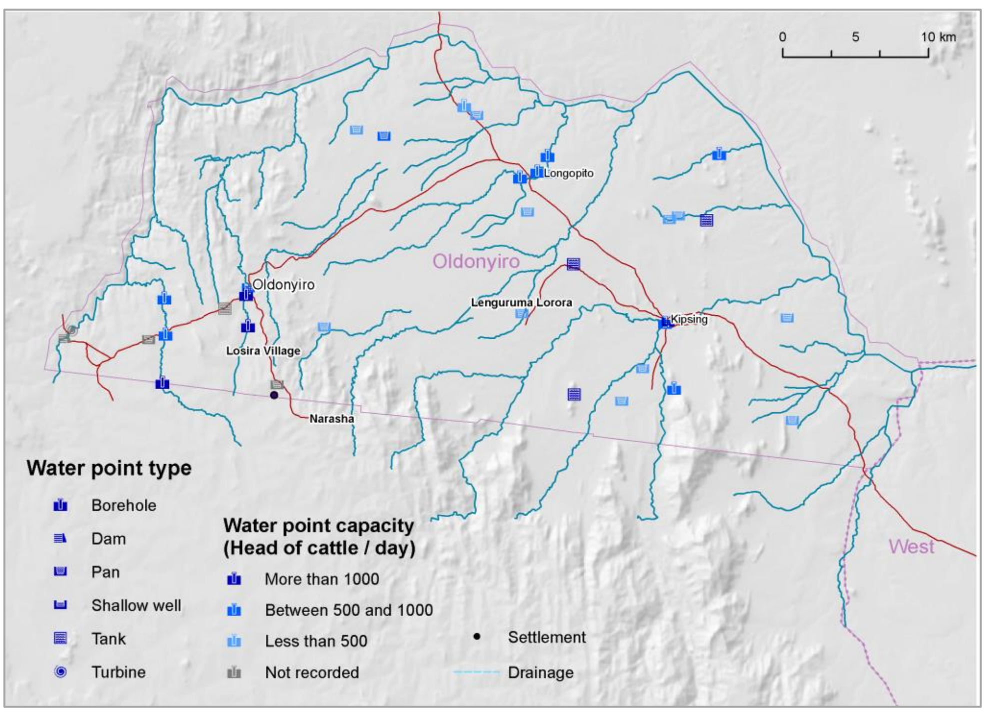

Figure 9 Oldonyiro Ward, Isiolo Count, Kenya, showing water point type and capacity.

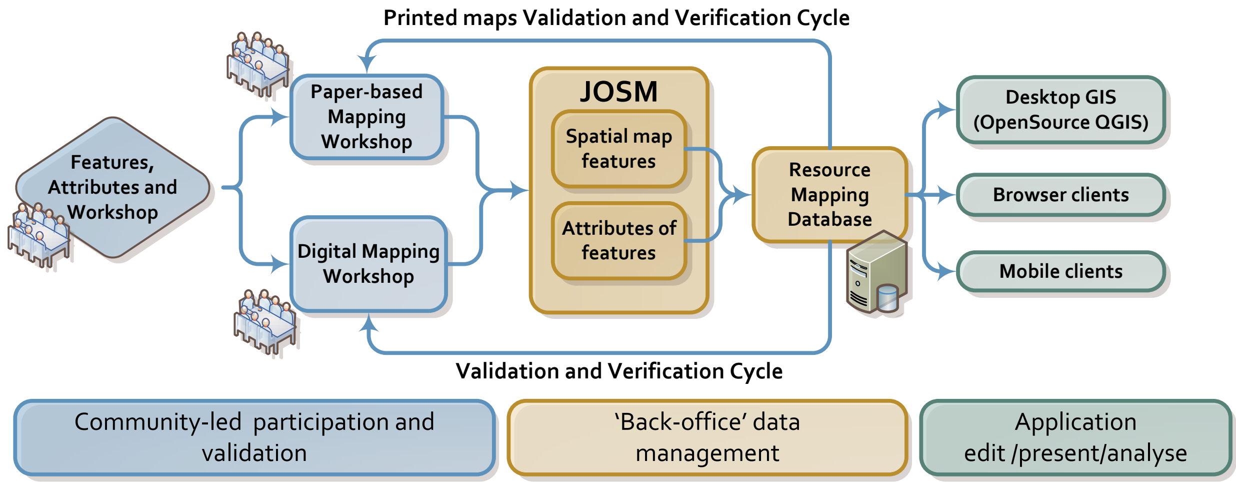

Figure 10 Illustration of the workflow and the data review and validation cycles developed in Isiolo, Kenya.

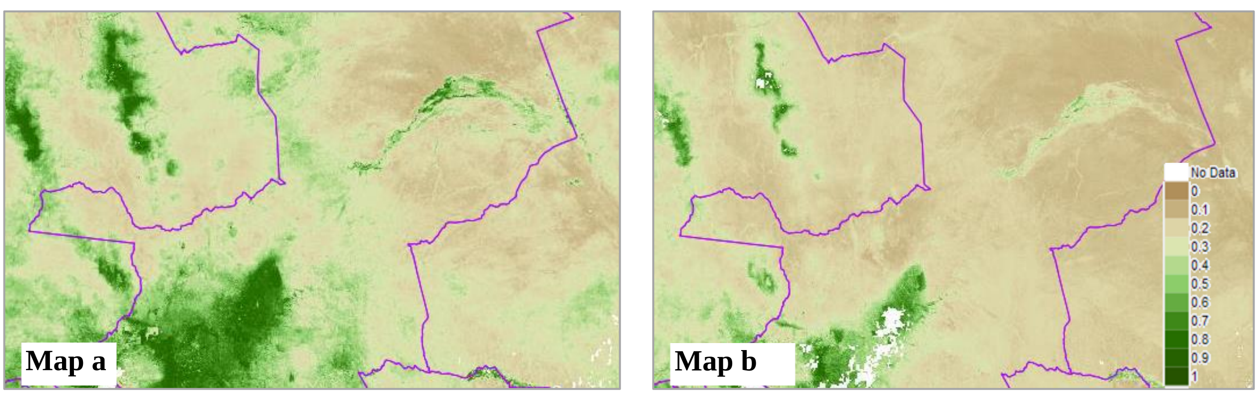

Figure 11 Normalised Difference Vegetation Index (NDVI) images integrated into the mapping environment: a) wet season, May 2014 and (b) dry season, July 2014. (*Source: U.S. Geological Survey*)

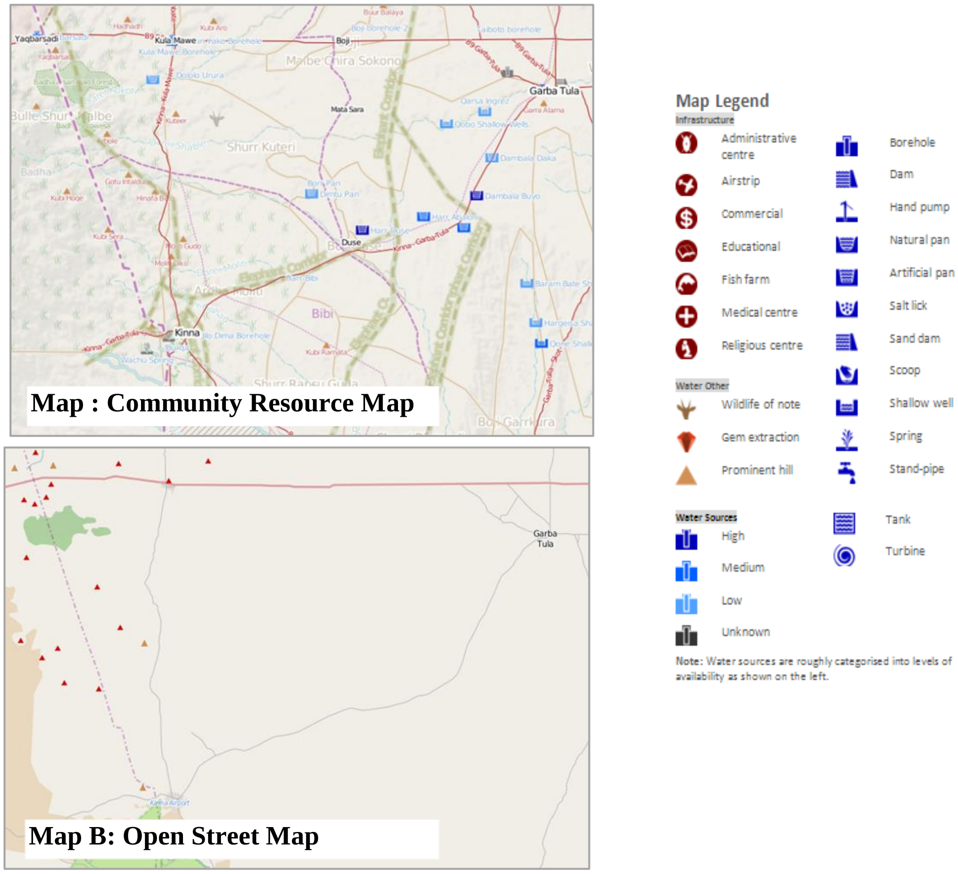

Figure 12 Contrast in the mapped features between the Community Resource Map (a) and existing Open Street Map (b) data for drylands between Kinna and Garba Tula, Isiolo, Kenya.

Figure 13 Online video of Isiolo community mapping of pastoralist resources (*YouTube*)

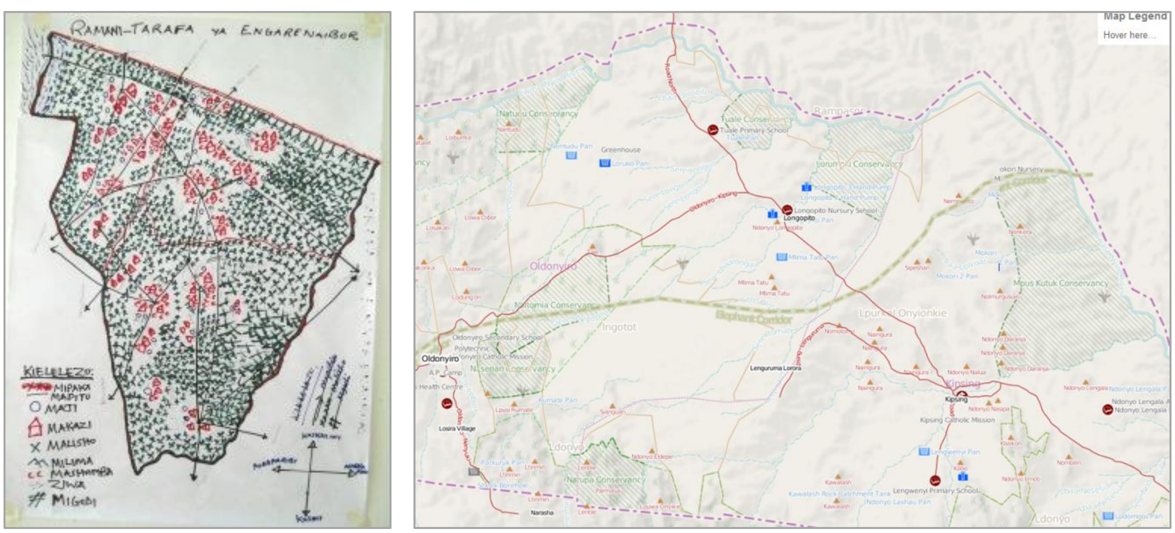

Figure 14 Comparison of paper perception maps and geo-referenced digital online geospatial datasets shows the accuracy of local knowledge in terms of distance and direction.

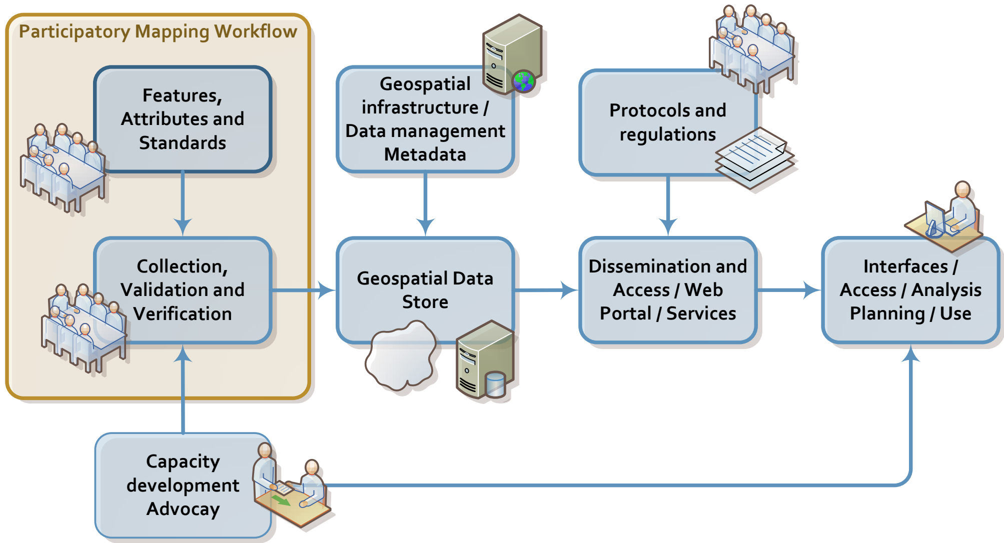

Figure 15 Integration of the participatory mapping workflow into the spatial data infrastructure for management and distribution of geographic information.