ABSTRACT

VALIDATING LOCAL INTERPRETATIONS OF LAND COVER CHANGES AT MT. KASIGAU, KENYA

by Njoroge Ikonye Gathongo

Landscape spatial and temporal changes are of critical importance in resource conservation. This study examined how the integration of remote sensing, geographical information systems, and local knowledge contributes toward understanding land cover changes in Jora and Makwasinyi villages at Mt. Kasigau, Kenya. Two research questions were asked. 1) How can local mapping contribute to the interpretation of historical and current land cover images? 2) How and why has land cover changed? Between June and July 2011, I carried out local mapping sessions, group discussions, and transect walks with focus groups of men and women in the villages. Current and past land cover types drawn on the participatory maps were overlayed onto a 2010 KOMPSAT-2 image. Residents described the emergence of woody plants at the historical mountain farms and loss of vegetation across the bushland. Whilst human activities posed a threat to the bushland, the montane forest was protected.

VALIDATING LOCAL INTERPRETATIONS OF LAND COVER CHANGES AT MT. KASIGAU, KENYA

A Thesis

Submitted to the

Faculty of Miami University

in partial fulfillment of

the requirements for the degree of

Masters of Arts

Department of Geography

by

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Oxford, Ohio

2012

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Chapter One

INTRODUCTION

African montane landscapes contain a diversity of material resources and ecosystem services that are critical to human livelihoods (Hurni 1999) and require sustainable management (UNEP 2002). The Eastern Arc Mountains are among the oldest mountains in East Africa that extend from Central Tanzania to Southeastern Kenya (Newmark 2002; Burgess et al. 2007). The region is recognized as a biodiversity hotspot because of its high species richness, high number of endemic species, and high degree of fragmentation in the remaining montane forests (Myers et al. 2000). The productivity and sustainability of natural resources in the Eastern Arc depend on how they are utilized, managed, and change over time in relation to human livelihoods (UNEP 2002). Under state and private management, property rights are secure, which can lead to the regulated management of natural resources (Meinzen-Dick et al. 1997). Much of the montane resources in the Eastern Arc, however, occur under a 'communal' common property regime that requires collaborative management among the communities who hold a vested interest in the resources and extra-local authorities who may wish to promote the protection of certain resources (Rocheleau 1999).

Empirical studies on how landscapes change over time can employ a 'scientific' approach, where researchers use various methods such as GIScience and ecological studies (Mbile et al. 2003). However, human activities are the primary drivers for land cover and land use change, which determine the composition, structure, and dynamics of a landscape (Hu & Hobbs 2002). Therefore, scientific studies on landscapes should integrate local knowledge in resource interpretations in order to understand *what* patterns are changing and *how* and *why* landscapes change (McCall & Minang 2004). Landscape ethnoecology, by design, focuses on: "the perception of the land, the parsing of its patterns, and the classification of its constituent parts" (Johnson & Hunn 2010, 1). By integrating local perceptions and 'scientific' methodologies, local residents will be included in a joint decision making process that can better inform authorities about the complexity of landscape change and provide collaborative opportunities for promoting resource sustainability (Mapedza et al. 2003).

Participatory GIS or "PGIS" emanates from participatory approaches in planning and spatial information management (Rambaldi & Weiner 2004). Participatory Rural Appraisal and Participatory Learning Action have played a significant role in the emergence of PGIS (Rambaldi et al. 2006). PGIS links local narratives with geo-spatial information tools such as satellite images, GIS, and aerial photographs (Rambaldi et al. 2006). Problems in landscape planning and management are usually complex and therefore, require involvement of all stakeholders. Through participatory GIS, disadvantaged communities are empowered to generate and manage spatial information (McCall & Minang 2004). PGIS integrates both expert and local skills to promote collaboration among stakeholders in resource management. Communities are able to map their resources, gain a sense of ownership in the created maps, and direct better governance of the resources (McCall & Minang 2004). By employing a participatory learning approach, outside researchers are able to work and learn from the local community, enabling opportunities to exchange ideas and jointly gain skills in land cover mapping and resource analysis (Nethengwe 2007).

Statement of Research Purpose and Questions

The purpose of this research was to investigate how the integration of remote sensing, geographical information system (GIS) techniques, and local knowledge can contribute toward understanding land cover changes at Mt. Kasigau, the most northeastern mountain in the Eastern Arc (Burgess et al. 2007). GIScience techniques can measure spatial patterns of land cover and document changes in land cover over time, but questions arise as to 'what' is changing in relationship to how landscape heterogeneity is classified and observed, and '*how'* and '*why'* land cover changes occur.

For this purpose, the study focused on land cover changes at two village locations surrounding Mt. Kasigau, Kenya. Past studies at Mt. Kasigau gained much ecological and ethnobotanical data on how resources are distributed and used by the Kasigau Taita (e.g., Medley et al. 2007), but little is known about how local land cover and resources have changed over time and the reasons for these changes. I investigated how local mapping of land cover types and features contributes to the interpretation of historical and current land cover images of Jora and

Makwasinyi. The study addressed two research questions in order to gain a better understanding of the pattern and processes of land cover changes.

1. **How can local mapping contribute to the interpretation of geo-referenced historical and current land cover images at Mt. Kasigau?**
   For this analysis, I facilitated mapping sessions with focal groups of men and women to plot and interpret historical and present land cover types and features in Jora and Makwasinyi. Land cover types and features mapped by the residents of these two villages were then overlayed on both a recent high resolution satellite image obtained by KOMPSAT-2, and geo-referenced historical aerial photos for Jora (1955) and Makwasinyi (1957). During the mapping exercises, I asked residents to focus on the spatial distribution of different past and present land-cover types, and to label locations of significance. Semi-structured interviews conducted during the local mapping exercise were used to provide a description of past land cover and available resources. The study particularly emphasized what has changed in the different land-cover types that were mapped by the residents.
2. **How and why has land cover changed at Mt. Kasigau?**
   This research question collected local interpretations of land cover changes and encouraged local analyses of causal factors that explain the patterns of land cover change. Collective analyses began from the interpretation of the local maps of Mt. Kasigau. Land areas village residents had designated to have significantly changed were visited during transect walks. They described the changes that had occurred and speculated on the reasons for those recognized changes.

Contribution of the Research

The overall goal of this research is to contribute to the sustainable management of natural resources by better understanding *how* and *why* landscapes change. Of particular importance is the identification of changes that promote or degrade productivity and the availability of natural resources. One such approach of improving management of natural resources over time by involving different stakeholders in resource governance is adaptive collaborative management, which relies on sharing information amongst stakeholders (Wilhere 2002). The research validated local narratives of land cover change for the adaptive management of natural resources.

Chapter Two

LITERATURE REVIEW

Theoretical Context: Intersecting Landscape and Human Ecology

The theoretical context of this research is situated at the intersection between theoretical developments in landscape ecology and human ecology. Discourse in landscape ecology views a landscape as a system that consists of elements (land-cover types) and a structural configuration that is complex and dynamic (Hu & Hobbs 2002). Landscape ecological studies clearly demonstrate how landscape patterns change over time in response to natural and human forces (Palang et al. 2000). These studies are supported by various scientific approaches such as remote sensing, ecological studies, and GIS (Mapedza et al. 2003). Landscape ecology especially focuses on how landscapes are structured and change in predictable ways that can be empirically modeled for analysis (Nagendra et al. 2004).

Theoretical developments in human ecology, however, suggest that the factors that influence human adaptive behaviors are equally complex with consequent unpredictable effects on landscape pattern and change over time (Berkes et al. 1998). Therefore, there is a need to integrate local knowledge on how landscape patterns are classified and how changes are perceived in relation to livelihood and resource relationships. Human ecology provides insights on how, and most importantly why human beings contribute to the landscape changes (Palang et al. 2000). Therefore, this research integrates discourse employed in landscape and human ecology toward understanding how landscapes change over time; what are the changes, and why do the changes occur? By gaining a collaborative view of landscape changes, the research validates local knowledge in the landscape management and the conservation of natural resources.

Landscape studies indicate that scientific knowledge on natural resource management does not work effectively alone and might cause more problems (Berkes et al. 1998). Local knowledge and perceptions are intrinsically important to sustainable development (Rocheleau 2007). A more holistic approach toward studying landscapes may be achieved by integrating local and scientific knowledge. Human beings are part of nature and a component of the environment, suggesting the importance of linking local knowledge with scientific knowledge. Local and scientific knowledge linkages contribute to sustainability and resilience of natural resources (Berkes et al. 1998). For instance, scientific ecological knowledge can lead to monitoring the changes that occur in an ecosystem, while local knowledge would be important to inter-generational sharing and narratives on why those changes occur (Berkes et al. 1998). Rocheleau (2008) recommends a trans-disciplinary approach that links the social domain of development and the biophysical domain equally, including teams working on ecology and ethno-ecology. From previous studies in South Asia and Africa, on the material and social effects of development intervention, a study conducted by Blaikie (1985) highlights the importance of maintaining an approach that focuses on both forms of knowledge (see Rocheleau 2008).

Theoretical Development in Landscape Ecology

The field of landscape ecology offers an explicit perspective on the relationship between ecological processes and patterns that can be applied across a wide range of scales (Turner 2005). Landscapes consist of heterogeneous and interacting ecosystems or land elements that are repeated similarly across space (Forman 1995). Carl Troll, a German geographer first used the term “landscape ecology” in 1938 and the field developed in close association with land planning (Turner 2005). Landscape ecology incorporates terms and ideas from other ecological fields but especially considers scale as a major concept (Forman 1995).

Landscapes are dynamic over time and space in their composition and structure (Burel & Baudry 1992). These spatial and temporal patterns are an outcome of diverse processes that occur in landscapes (Forman & Godron 1986; Turner 1989). A landscape may be viewed from different perspectives that holistically examine its spatial and temporal dimensions (Palang et al. 2000). As an ecological system, landscapes are characterized by their composition, structure, and dynamics (Turner 1989). These attributes uniquely include both vertical and horizontal dimensions within and across places, respectively. Landscapes are heterogeneous, consisting of a mosaic of patches across space and structurally complex layers within a land-cover type (Bastian & Steinhardt 2002). Changes in landscapes occur at different rates and magnitude, which can help define landscapes in relation to causal agents (Antrop 1998).

Landscape ecologists are interested in understanding and predicting changes in landscape structure over time in response to natural and human disturbances (Turner 2005). Studies in landscape change over time demonstrate the interplay between nature and society. Anthropogenic factors acting on landscapes have been recognized as critical factors that contribute to landscape change (Nagendra et al. 2004). Humans interact with landscapes in complex ways and at different scales (Giannecchini et al. 2007). Human forces acting on landscapes change the composition and distribution of landscape elements.

Technological advancements in the fields of remote sensing and GIS have contributed to the development of landscape ecology. These advancements make it possible for landscape ecologists to quantify the magnitude of change at different temporal and spatial scales (Veldkamp & Lambin 2001). Aerial photographs and satellite images both provide measures of land cover (Giannecchini et al. 2007). Methodologically, landscape ecologists have used remote sensing techniques for studies that relate spatial patterns to land use processes (Nagendra et al. 2004).

Theoretical Developments in Human Ecology

Theoretical developments in human ecology emanate from the study of relationships between humans and their natural environment (Walters & Vayda 2009). These relationships contribute to landscape changes over time (Berkes et al. 1998). Understanding the interaction between humans and nature is necessary to better understand how and why landscapes change. Literature on the interaction between humans and the natural environment emphasize both temporal and spatial patterns in these relationships (Walters & Vayda 2009). Unlike ecology, which may view humans as external to landscapes or ecosystems, human ecology uses an ecosystem perspective that explicitly includes humans and their social systems (Berkes et al. 1998). One argument by Walters and Vayda (2009) on event ecology highlights the importance of first understanding landscape change locally before proposing and evaluating causal theories and hypotheses. Causal histories rely on local communities and their narrative interpretations.

Community participation is important in the decision making process in natural resources management. The emphasis on participatory natural resource management comes from the wisdom that communities understand their problems and they hold the solutions to the problems (Agarwal 2001). Communities are the providers of information on the causes of landscape change and are in the best position to highlight local solutions (Sekher 2001). Humans, however, view landscapes in different ways, depending on the resources the landscape provides and their livelihoods (Medley & Kalibo 2005).

Who participates and who determines who will participate in decision-making processes are issues that raise concern in heterogeneous communities (Agarwal 2001). Participation needs to be inclusive. Local community participation in decision-making processes in natural resource management may lead to better governance of landscape resources (Agarwal 2001). Moreover, the knowledge held by local residents may contribute information that is required for better landscape management. Altogether, this research tries to better validate local knowledge and its contribution to the conservation of natural resources.

Methodological Context: GIS in Land-Cover Change Analysis

The methodological approach used in this research links GIScience and participatory research. Participatory GIS relies on linking local interpretations (narratives) to a georeferenced base map. When using aerial photographs to construct the base map, distortions that are contained in the photographs should be removed (Rocchini & Rita 2005). The first step entails scanning the photos to construct a digital image (Kadmon & Ruthie 1999). Scanned images are rectified through the collection of ground control points (GCPs) from a geo-referenced map of the area (Massasati 2002). GCPs are used in transforming the scanned image from the photo coordinate system into the map projected coordinate system (Bolstad 2008). GCPs used for the georectification processes are obtained from digital image data of a registered coordinate system (Bolstad 2008). GCPs should be from a source that provides the highest feasible coordinate accuracy; they should be evenly distributed and be selected from features that are easily identifiable (Bolstad 2008).

Georeferencing is another important process of determining the spatial location of geographical features to the relative position on the earth’s surface (Massasati 2002). Georeferencing is done by linking visible points in an aerial photo or satellite image with real earth coordinates. This process can be done by collecting GCPs of features that can be identified in satellite images or aerial photographs such as road intersection, houses, and water points among others. GCPs should be evenly distributed throughout the photo to ensure accurate georeferencing of an image. Once GCPs are collected, georeferencing of air photos and satellite images can be done using GIS software such as ArcGIS, ArcView or ERDAS Imagine. After georeferencing, the images can be displayed in GIS software with their precise location (Massasati 2002).

Many studies have employed GIScience in the analysis of land cover changes. A study done by Mosugelo et al. (2002) utilized satellite images to determine vegetation change in landscapes for a span of 36 years in Chobe, National Park, Botswana. Mosuelo et al (2002), found that there was a considerable decrease in shrubland, woodland , riparian forest, and mixed woodland between 1962 to 1998. Similarly, aerial photographs acquired at different periods in time were used to map landscape changes in Mafungautsi Forest, Zimbabwe (Mapedza et al. 2003).

Methodological Context: Participatory Mapping and Research

According to Chambers (2006), participatory mapping of resources by the local communities has been practiced for a long time. Local communities mapped resources and other features by painting on walls, without any facilitation from outside. However, mapping resources with outsider's facilitation is now a popular tool in participatory rural appraisal and participatory research (Chambers 2006). Participatory GIS is a tool used to gain a pictorial representation of landscapes from communities (Mbile et al. 2003). As a resource mapping tool, Participatory GIS can be used for mobility mapping, social mapping, health mapping, and other applications (Chambers 2006). The increase in interest in Participatory GIS is because the activity has the potential to empower local communities through their participation (McCall & Minang 2004). Participatory GIS allows the local community to map their own resources, gain ownership of the map or decision-making tool, and use the map to direct local and extra-local governance of resources (McCall & Minang 2004).

Participatory mapping can be effectively integrated with field research for collaborative learning between the local residents and the facilitators (Medley & Kalibo 2005). Participatory research can be conducted in different ways according to the research being undertaken. Medley and Kalibo (2005) carried out research on gaining an understanding of how communities view their landscapes and they did this by interacting with the community in their daily activities in order to understand and learn from them. Through this, a researcher is able to learn more while utilizing unstructured questionnaires in the community. Semi-structured questionnaires help in understanding how and why landscapes change. The use of semi-structured questionnaires has been undertaken by Mapedza et al. (2003) to understand how landscapes change. The researchers interpreted current landscapes constructed from aerial photographs by the community in a participatory mapping exercise. By linking semi-structured interviews with participatory mapping of landscape changes, researchers can better understand the causal agents of landscape change. Transect walks in landscapes can also be used to examine land cover change (Mapedza et al. 2003). Transect walks provide additional information to substantiate community perspectives on land cover change (Robiglio & Diaw 2003). Participatory GIS integrates methods in GIS and participatory mapping to gain a perspective on local land cover that has local meaning and is geo-registered for spatial analyses (Dunn 2007)

Participatory GIS has received some criticism by researchers who have suggested that its application would cause alarm, fear of exploitation, misinterpretation of knowledge, or intellectual mining of community knowledge on resources (Tripathi & Bhattarya 2004). Another ethical issue associated with the use of PGIS is that it has been criticized to be a tool that wastes the time of the rural poor who sacrifice their time to participate in research, thereby foregoing their daily chores (Chambers 2006). Furthermore, if the mapping exercise is poorly designed, the project can potentially disempower vulnerable and underprivileged groups by not involving them in the participatory process (Tripathi & Bhattarya 2004). Another critique of PGIS is that it is a process, which is facilitated by outsiders and therefore it is liable to raise expectations of extra-local support to the participating communities (Chambers 2006). In order to be effective, PGIS should lend emphasis to the information that is being collected from the locals (Tripathi & Bhattarya 2004), and the PGIS information should assist in decision-making processes in the community. Resource managers have used land cover maps generated through participatory mapping and local narratives to determine changes in land cover. Other studies have relied on participatory methods in exploring local understanding of landscape history and for mapping (Robiglio & Diaw 2003).

Chapter Three

THE STUDY AREA

Mount Kasigau is located in Taita Taveta District, Kenya (38° 40" E, and 3° 49"; Figure 1) on Community Trust Lands in a corridor between Tsavo East and West National Parks. It is the most northeastern and isolated mountain in the Eastern Arc, located 50 km from the Taita Hills and 100 km from the Usambara Mountains in Tanzania (Medley & Kalibo 2007). The geological and climatic history of the mountain helps to explain high species richness, while topographic heterogeneity influences local patterns of forest-type diversity. Mt. Kasigau is distinct because of the very steep rise to its summit from 600 m to 1641 m in about two kilometers, and the current location of human settlements only at the mountain's base much below evergreen forest (Medley & Kalibo 2007). Approximately 200 ha of evergreen forest above 1000 m are gazetted as a forest reserve while the Kasigau Conservation Trust coordinates local resource management on community lands.

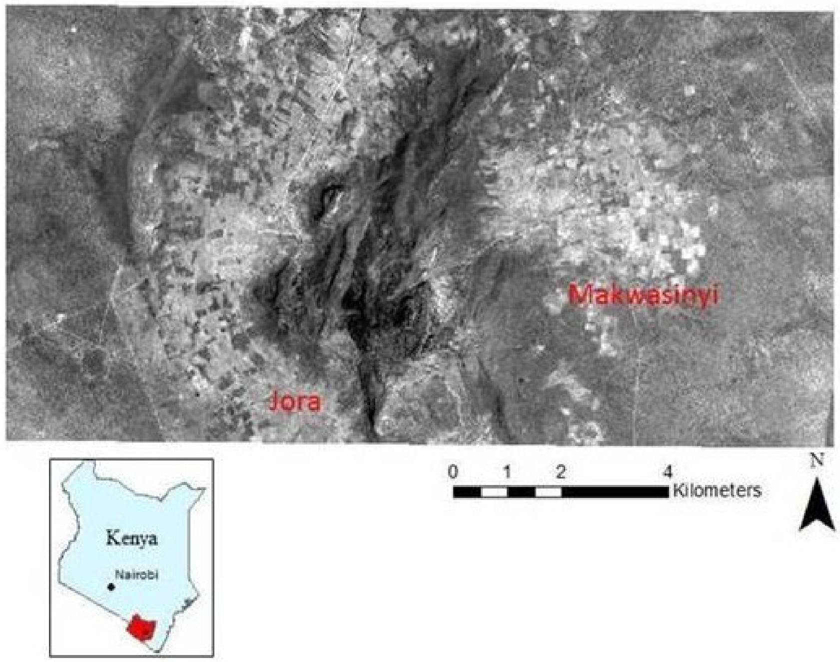

Figure 1. Location of Mt. Kasigau in southeastern Kenya (Taita Taveta District) and the two study villages at the base of the mountain (Makwasinyi and Jora).

Subject Population: The Kasigau Taita

This study was based in the villages of Jora and Makwasinyi (Figure 1). The inhabitants of these villages are Kasigau Taita (a subgroup of the Taita), who are part of the Bantu speaking people of Kenya. The Kasigau Taita depend on small-scale farming and livestock (Kalibo 2004). Farming is conducted on the lowland where they cultivate mostly pigeon peas, beans, and maize (Figure 2). Farmers within the area also keep goats and chicken as an alternative source of income. Communal cattle grazing is a major activity undertaken by the Kasigau Taita in the bushland below their farms (Kalibo 2004).

In 2003, Kalibo (2004) facilitated participatory mapping sessions with women and men residents in Jora and Makwasinyi. Their participatory maps particularly focused on the distribution of woody plant resources and how resource distributions changed over time since their re-settlement to Mt Kasigau in the mid-1930s. These maps helped to define the approximate land areas settled and used by the two villages.

Figure 2. Livelihoods of the Kasigau Taita. a) Small-scale maize farms in Jora. b) Harvested pepper in Makwasinyi village.

Chapter Four

DATA AND METHODS

The research employed GIScience and qualitative techniques to examine *what*, *how* and *why* land cover has changed in Jora and Makwasinyi villages. Prior to undertaking the research, I fulfilled the research requirement of informed consent, which was approved by the Institutional Review Board at Miami University (Appendix 1). I also received a clearance certificate from the Ministry of Education, Science, and Technology in Kenya to conduct my research registered as NCST/RRI/12/1/SS-011/889/4 (Appendix 2). During the fieldwork, I relied on the use of Kiswahili, the national language of the Republic of Kenya, for communication. However, in some instances conversations were translated from Kiswahili to Kitaita and vice-versa.

Between the months of June and July 2011, I conducted field research in the two study villages. Upon arrival to Mt. Kasigau, I contacted a volunteer with Mt. Kasigau Conservation Trust at Rukanga village, Mr. Mwangi, who introduced me to some of the residents of Jora village. Drs. Maingi and Medley, who were in the field, introduced me to Mr. Joseph Mwamodo who became my principal local field assistant. I explained to Mr. Mwamodo the purpose of the research and then we visited the chief, assistant chief, and the local elder in Jora village where I introduced myself and described the purpose of the research. I gained their support to seek permission and assemble groups of men and women residents for the mapping sessions and focused group discussions. We then conducted a familiarization tour in Jora before proceeding to Makwasinyi, where Mr. Mwamodo, introduced me to Mr. Mwamba, who become my local contact person in Makwasinyi. During the familiarization tour in the two villages, my local research assistant introduced me to two men and women in each village where I described the purpose of the research. The men and women in each village assisted in the mobilization of village residents for the mapping sessions and group discussion.

Figure 3. Local mapping session in Jora village

Landscape Patterns and Change

Geo-registered base maps for the study area were compiled from a 1 m resolution panchromatic KOMPSAT-2 image taken in February 2010. Korea Multi-Purpose Satellite-2, abbreviated as KOMPSAT-2 and also referred to as Arigang-2, was developed by Korea Aerospace Research Institute (Lee et al. 2008). The satellite was launched into space in July 2006. KOMPSAT-2 satellite contains four multispectral bands of 4 m resolution and one panchromatic band of 1m resolution (Seo 2008). During this research, I used the 1 m resolution panchromatic band (black and white). The satellite circles the earth 14 times a day and operates in a sun-synchronous orbit (Lee et al. 2008). The satellite orbits the earth at an altitude of 685.13km with an inclination of 98.127° (Seo 2008). I used the 1 m resolution panchromatic band rather than the 4 m multispectral band due to its high resolution.

The KOMPSAT-2 image was geo-rectified using Google earth co-ordinates and then the two village areas were extracted. I went to the field with a geo-registered KOMPSAT-2 image for each village area and carried out two gender-based participatory mapping sessions in each village. I conducted the first mapping session with 16 women participants from Jora, aged between 40 to 75 years, who assembled outside the office of the Jora women basket weavers' hall for approximately six hours. I provided them with a geo-registered KOMPSAT-2 image of the village, manila papers, erasers, different color makers, transparencies, and pencils. Before they began the mapping exercise, I explained to them why I was conducting the research and described how the participatory mapping exercise is carried out. I also showed them a copy of the participatory map Jora women residents had conducted earlier (Kalibo 2004). However, the residents were not comfortable using the KOMPSAT-2 image as a base map. They first drew their own maps and then labeled some places on the image. The current landscape was mapped first before mapping the historical landscape.

The other participatory mapping sessions followed a similar protocol. I met with a group of men in Jora aged between 55 to 80 years. On the mapping day, 14 participants assembled at Mzee Harrison homestead where they were provided with similar mapping tools. The men first drew their own maps before labeling some place names and features on the geo-registered image (Figure 3). In Makwasinyi, I held mapping sessions with a group of 12 men and 14 women assembled at Makwasinyi Presbyterian Church of East Africa (PCEA) church on different days.

The mapping of past land cover was carried out after the residents completed mapping the current landscape. In mapping the historical landscape, the group of men and women in each village discussed how the landscape was in the late 1940's to 1950's. The participants in each village discussed how the landscape was in the past and depending on the level of consensus among the participants, the group of men and women mapped different land cover types. The mapping sessions provided an opportunity for the participants to describe and show the distribution of land cover types and map places and features. The maps created by the residents were used in analyzing how local mapping of land cover can contribute to the interpretation of geo-referenced maps in understanding land cover changes.

Residents mapped the spatial distribution of land cover types, place names, and features that were then transferred to the georegistered images of the study areas. I digitized the current and historical land cover types that they mapped onto the 1 m resolution panchromatic KOMPSAT-2 images extracted for the villages. Using the boundaries that were marked on the participatory maps, I further delineated the boundaries on the geo-registered KOMPSAT-2 image. Using the land cover types and features such as roads that were marked on the local maps, I delineated the boundaries on the geo-registered KOMPSAT-2 image by clipping the KOMPSAT-2 image in ERDAS Imagine. Approximate locations of land cover types mapped on the local maps were eventually digitized on the KOMPSAT-2 image in ArcMap. To calculate the area of the different land cover types namely; woodland, bushland and farmland, I used the “calculate geometry” tool found in ArcMap. To begin with, I opened the attribute table of each land cover type class I had digitized and added a new area field while in the edit session. Secondly, using the calculate geometry tool while in the edit session, I calculated the area of each land cover type of the historical and present land cover types polygons that I had digitized and manually calculated the percentage land cover changes. The study examined how the distribution of land-cover types changed over time, their respective land areas, and the significance of the locations mapped by the residents at the two time periods.

I also compared historical photos of the study villages with the 2010 KOMPSAT-2 image to show places where land cover had changed or remained stable. Historical air photos at a scale of approximately 1:32,000 were acquired for Jora (February 1955) and Makwasinyi (February 1957) from the Department of Survey, Kenya. The historical air photos for Jora and Makwasinyi had poor spatial resolution and quality, which made the georectification and interpretation difficult. For instance, some of the air photos contained distortion from poor processing of the film creating blurry image. I, therefore, focused on the comparison of small areas when comparing the air photos and the KOMPSAT-2 image. I used the geo-rectified the KOMPSAT-2 image to geo-reference the scanned photos for the study area in ArcGIS and compared land cover for sample locations on both the historical and current images.

How and Why has Land Cover Changed?

Once the resource maps compiled by the residents were complete, I conducted a gender based group discussion to understand how and why land cover/land use patterns have changed. The aim of these conversations was to discuss and expand on the causal factors of land cover changes in the two villages. The discussions were centered on the local maps the residents had drawn and each group member was encouraged to contribute his/her views on the causal factors of land cover changes in the area.

On later days, after the participatory mapping sessions, I carried out transect walks in the two villages. From the mapping session participants, a smaller group of men and women participants agreed to go on the transect walks. While walking with the groups, we traversed specific land cover types that were mapped by the community in their participatory maps and I recorded narrative descriptions of land cover/land use changes. During these walks, I provided questions to the group of men and women to facilitate discussion of the changes observed:

1. *Can you describe how the land looked like in the past?*
2. *How has the location changed since the 1950s?*
3. *Which resources were here in the past and are still present?*
4. *How have the resources at this location changed?*
5. *Why have these land and resource changes occurred?*

These questions were important in the analysis of how and why land cover/ land use patterns have changed in Mt. Kasigau.

Chapter Five
RESULTS

Landscape Patterns and Change

Current Landscape Conditions

The current landscape patterns in the two villages include different land cover types described by the local residents and shown on their participatory maps. I digitized the distribution of bushland[1], woodland[2], forest, and farms on to the 2010 KOMPSAT-2 image (Figure 4). In Jora, the participants distinguished farms on lateritic and black cotton soils and showed a housing settlement at the village center (Figure 4). On their participatory maps and also shown on the KOMPSAT-2 image, the residents drew boundaries between some farm plots, which were defined by fencerows of shrubs and trees. Participants in Jora drew small parcels of farms near the Rukanga-Bungule road and around the concentrated settlement while larger farms were located toward the bushland, which is clearly visible on the KOMPSAT-2 image (Figure 4). In Makwasinyi, participants did not map a concentrated settlement, homes were widely distributed between the farms and woodland from the shopping center toward *Kirongwe* and *Tombolo* (Figure 4). Many homes are distributed within their farms. In Jora, the participants show the settlement at *Ngambenyi* but a much smaller number of homes within the farmland. The groups of men and women at the two villages used different symbols on their participatory maps to distinguish the distribution of forest, woodland, and the bushland. Makwasinyi residents outlined rocky areas around the mountain, which contained sparsely distributed vegetation cover. Additionally, participants from Jora mapped major roads that were located in the area and a

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[1] The area is predominantly occupied by *Acacia* (and *Commiphora*) species and grassland. Wildlife is also present within the area as described by the residents of Mt. Kasigau.

[2] Transitional area between the bushland and the forest. The area consists of trees that are not tall and the canopy is open as described by the residents of Mt. Kasigau.

number of footpaths. Two rivers (*Mwangeta* and *Kamwandugi)* located in each respective village were mapped by the participants and shown on the maps (Figure 4).

The residents especially identified and named significant places and features on their maps (Figure 4; Appendix 3). In Jora, both the men and women residents identified *Cairo*, *Mwakuri,* and *Ngambenyi* as settlements that include farms on the lateritic soils. Mapped farms in *Ngambenyi* were evidently larger than in *Cairo* and *Mwakuri*. *Itoronyi*, which is a bushland utilized for grazing, fuel wood, charcoal, and building materials, was also identified by the male and female participants of Jora. Another important area that was named by both groups in Jora was *Ilenyi*, which is the area that contains the black cotton soil with small sized farms. *Ingire*, which is recognized as an important water catchment area, was identified by the Jora women participants in their local map. Women participants in Jora identified *Bawawi* as a grazing area on their map and named all the mapped roads while the men drew only the Rukanga-Bungule road and the road leading to *Bawawi*. *Viriwenyi*, which is a place located in the woodland on the northern part of the mountain, was named in the local map drawn by the men while the women participants in Jora named *Jogolo,* a dam in the bushland. *Ding' Ding'*, which is a rock outcrop located on the western part of the village, and *Mwandolo* cave to the east are two prominent features mapped by Jora participants near their village boundary to the northwest and southeast, respectively (Figure 4). The shopping center and school, which are located in the settled area, were also identified by both men and women in their local maps and geo-registered on the KOMPSAT-2 image (Figure 4). Along the woodland and near the settled area, there were places that were identified by both men and women on their current maps that could not be geo-registered in the KOMPSAT-2 image: *Mwangondi*, *Mkongo*, *Kwa Mashaka*, *Ndomokonyi*, *Kwa Luka,* and *Kibotonyi*.

Participants in Makwasinyi identified and described several places on their local maps. The male and female participants identified *Tombolo* and *Kirongwe* as farms that were located north of the central village and had homes within them (Figure 4). The men and women participants mapped *Mukufinyi*, which is a water intake point, located between the forest and woodland (Figure 4). The women participants named *Lalakunyi*, *Ngondoma,* and *Mkungonyi* as areas within the farmland that were located on the eastern side of the shopping center with homes interspersed within the farms. However, in the men's map, they did not name the places but only mapped scattered homes within the farms. The men and women participants, mapped *Mwakasau* and *Makanda* as places located within the woodland and bordering Bungule (Figure 4). *Isume*, which is a place located deep inside the forest and below the peak of the mountain was identified by the men and women as a water catchment area. Another place identified by both men and women was *Mavore*, which is located along the edges of the woodland and the farms near the shopping center. On the northern part of the mountain where the terrain was gentle, the men and women participants identified *Ikurungunyi* and *Karima-Ka-Gona* as exposed rocky areas containing sparsely distributed vegetation cover (Figure 4). Additionally, the participants described *Igweja fuwe* as erosional areas located near the shopping center. The summit of the mountain is called *Nyangala,* described as a rock feature that does not have vegetation (Figure 4). The men and women participants named and described several natural dams located in the bushland as water holding points for wild animals and cattle (*Mkandanga*, *Mjindu, Ndashinyi, Iriwa jakoba, Mwangenyi, Koba and Mkungo*). The men labeled seven dams and the women show only five of them. Only two dams were visible on the KOMPSAT-2 image, the others were lower in the bushland outside of the image area.

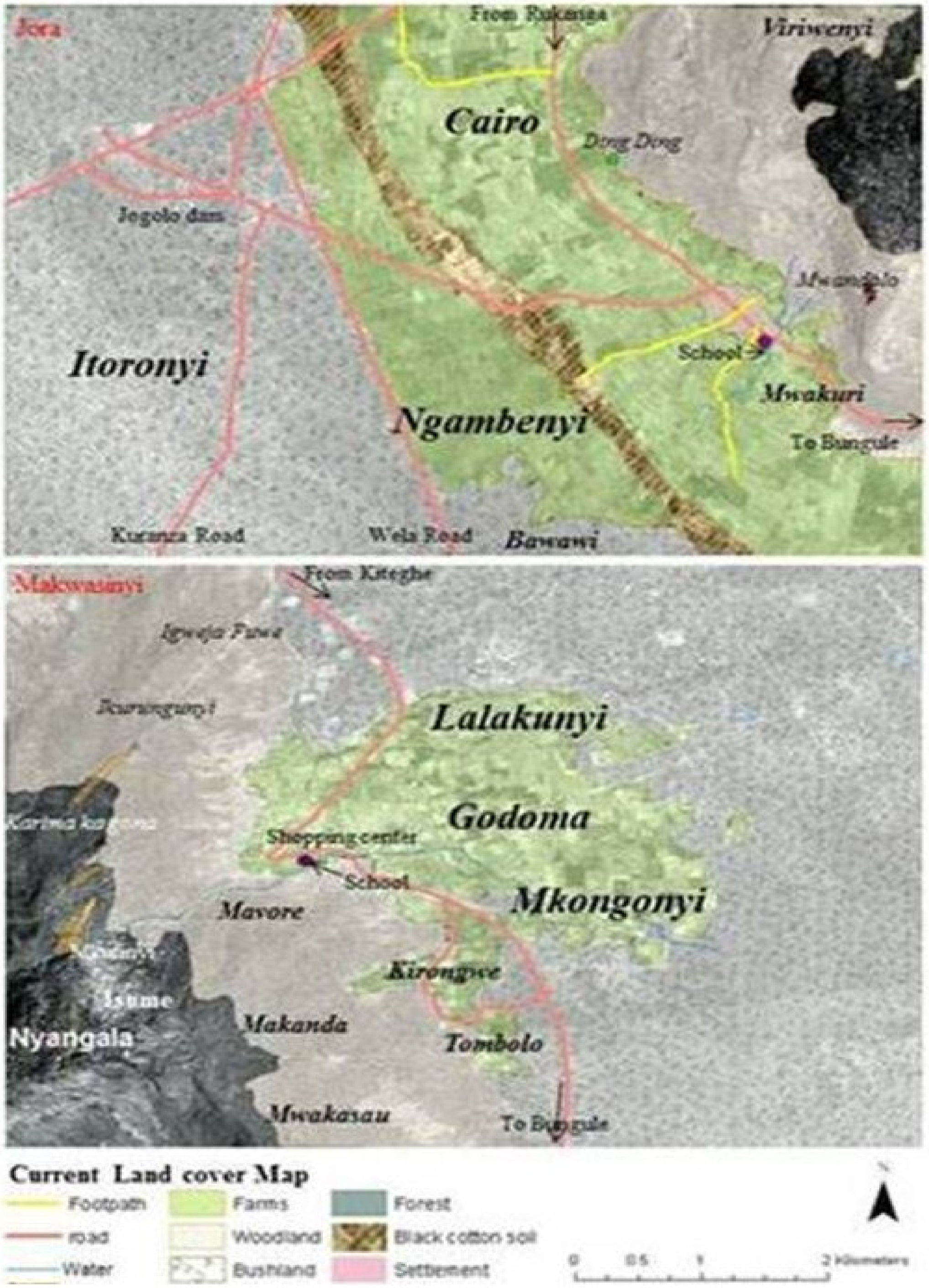

Figure 4. Present land cover for Jora and Makwasinyi compiled from the participatory mapping sessions and digitized onto the 2010 KOMPSAT-2 image.

Land Cover and Land Use Changes

The analysis of land cover changes was done through visual comparison of historical and current land cover types mapped by the participants and geo-registered on the KOMPSAT-2 image (Figures 4 and 5). During the mapping sessions, the men and women mapped historical land cover types for a time period between about the 1940's to 1950's. All participants mapped five main land cover types: bushland, woodland, forest, settlements and farms. At both locations, men and women participants mapped settlements on the mountain (*Ndomokonyi* in Jora, *Kijala Cha Waka*, *Kigondika*, and *Mwajombo* in Makwasinyi), and they also show farms on the mountain and in bushland (Figure 5). The women in Jora also mapped a village settlement before *Ndomokonyi*, (i.e. *Kifumbu*), within forest. In Jora, the participants uniquely show the early establishment of farms on the black cotton soil. The men and women also mapped historical farms at *Mwakuri* in the bushland and across the woodland below the village settlement (i.e. *Kwa Munana* and *Kibutonyi*) (Figure 5). In Jora, the men mapped a more dense bushland below the black cotton soil and less dense bushland along the main road. Makwasinyi residents also outlined large rocky areas around the mountain, which contained open vegetation (Figure 5). The participants mapped widely distributed homes across the woodland including named settlement at *Mwajambo* and *Kijala Cha Waka*.

The largest land cover change calculated in ArcMap for both maps is the conversion of bushland to farmland and settlement (Figures 4 and 5). These changes were computed as the summed difference between the land areas in hectares mapped for all polygons in each land cover type. In Jora, there was an increase of farming areas by 770% from 2 ha to approximately 14 ha, while the woodland and bushland decreased by 10% and 43%, respectively (from 5.3 ha to 4.9 ha in the woodland; from 25 ha to 14 ha in the bushland). In Makwasinyi, the bushland decreased by 62% (29 ha to 21 ha), while the farming area and woodland increased by about 366% and 16%, respectively (1.6 ha to 14 ha in farmland; 16 ha to 13.9 ha in woodland). My findings concur with earlier research by Medley and Kalibo (2007) who also show a shift of population to near the main road after the 1950s. Historical clearings mapped by the residents on the mountain now show up in the KOMPSAT-2 image as regrowth woodland.

The residents also named places and features on their historical maps (Figure 5; Appendix 3). In Jora, the groups of men and women again identified *Mwandolo* and *Ding' Ding'* and Makwasinyi participants mapped the mountain's summit at Nyangala (see also Figure 6). On the Jora men's map, they named *Mghongo Ghwa Mbisi* as a large rock located near the boundary with Bungule village. *Kwa Munana* mapped on the historical map by the women is named *Cairo* on their current map and defines a farmland sharing a boundary with Rukanga. The men participants in Jora uniquely identified locations along the river named after the people who lived there, including *Mkongo*, *Sangambunyi*, *Kwa Mashaka*, *Mwangeta*, *Mwasungita,* and *Mwashindi*. All participants in Makwasinyi named different settlements, including *Kirongwe, Kigondika, Kijala Cha Waka, Ndiwa, Karima Ka Gona* and *Mwajombo*. These places had both farms and homes. Men participants also described *Godoma* and *Mkungonyi* as farms in the bushland and *Isume* as a farmland higher up on the mountain. Along the river named *Kamwandugi*, which originates in *Mkufinyi*, the men and women identified sections named after the people who lived there, including *Ndiwa, Mwerinyi, and Kwanzia*. The men and women also identified different farms across the woodland that could not be geo-registered on the KOMPSAT-2 image (i.e. *Ilao, Mwakambata, Ngombenyi, Mzuzinyi, Kivuta Mbeo, Malombo, and Ribe*).

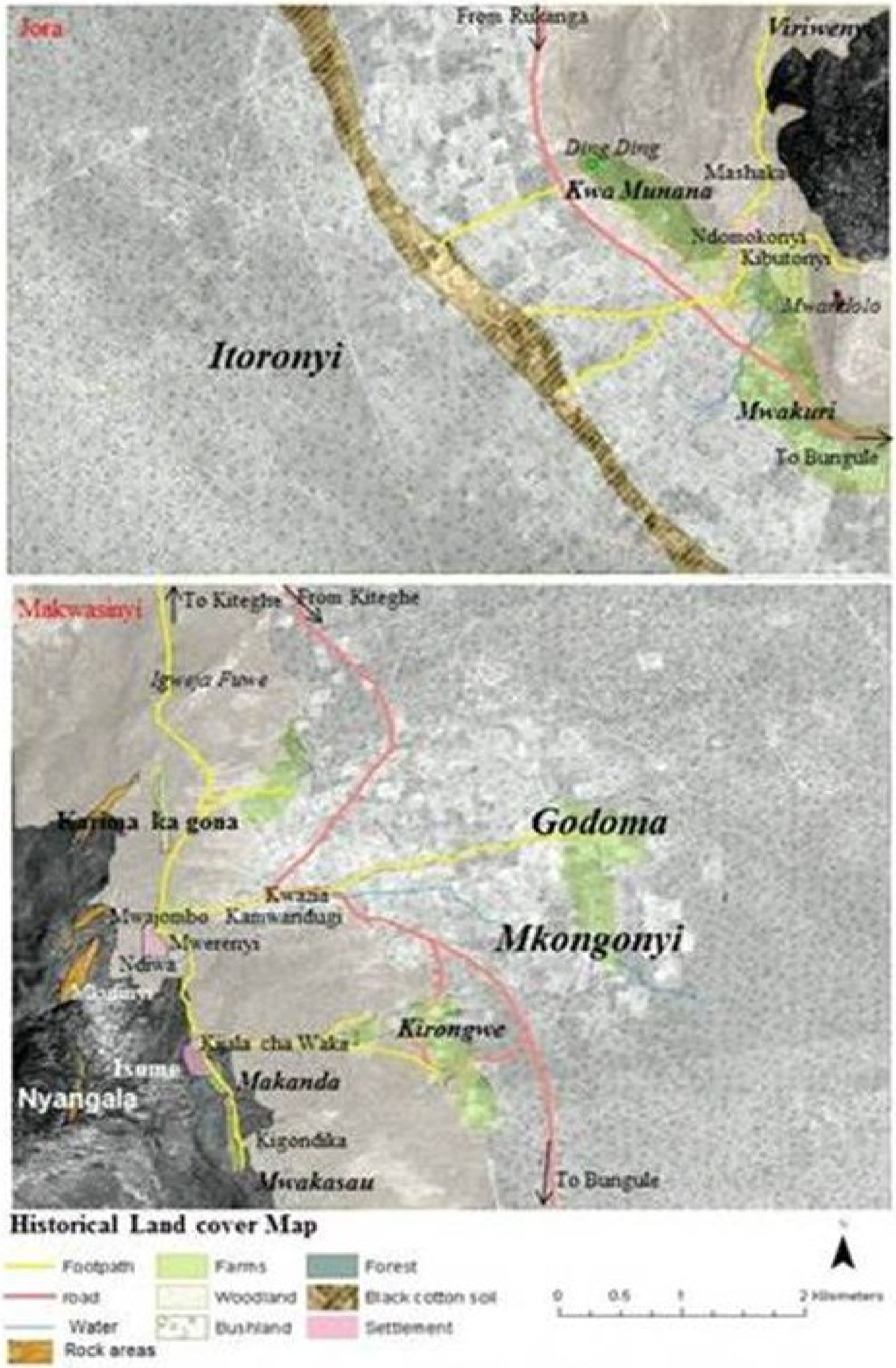

Figure 5. Historical land cover maps for 1940's to 1950's compiled from the participatory mapping sessions in Jora and Makwasinyi and digitized onto the 2010 KOMPSAT-2 image.

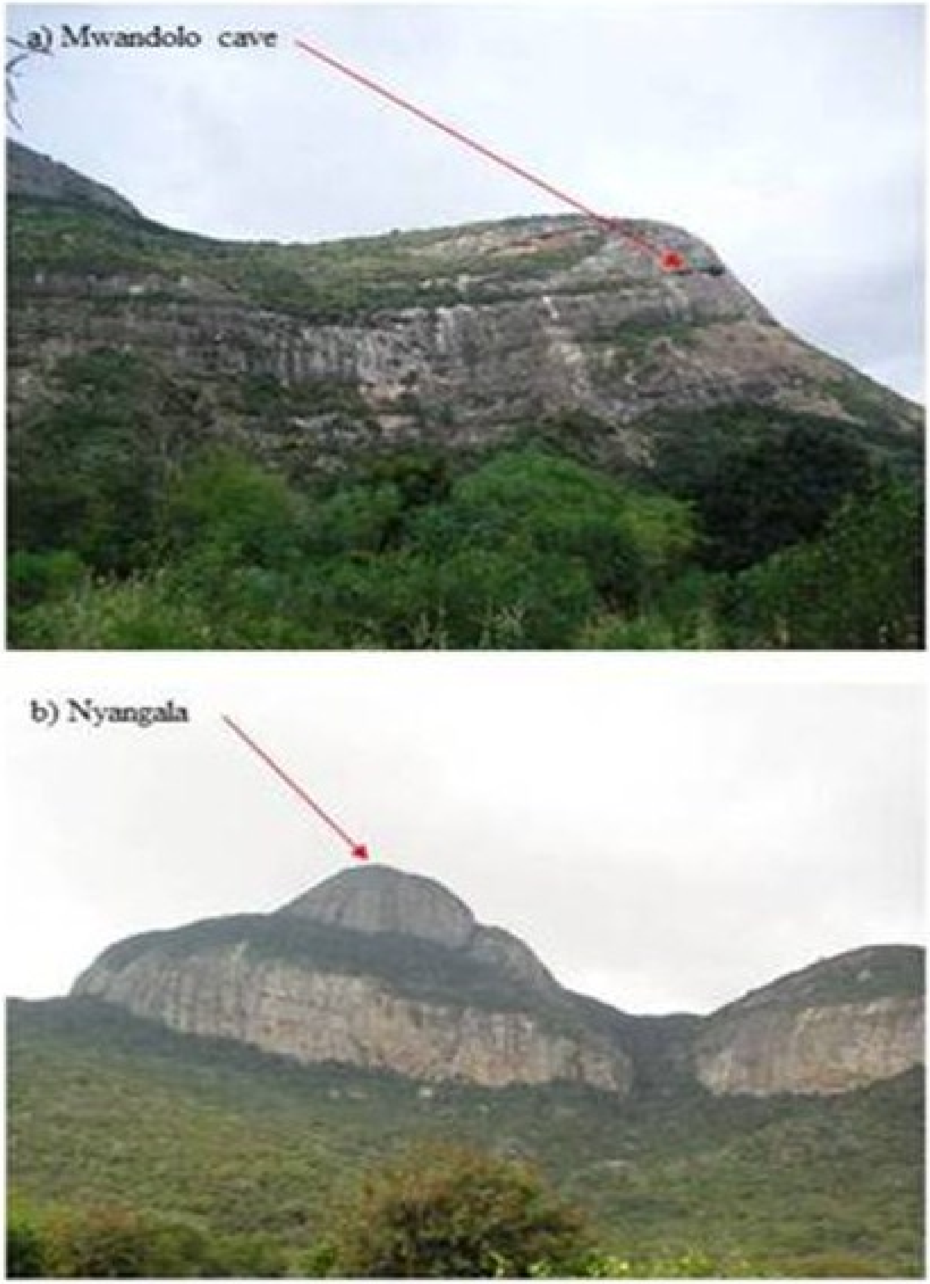

Figure 6. a) *Mwandolo* cave located northeast of Jora. b) *Nyangala*, the mountain rock summit above Makwasinyi.

Visual comparisons of locations on the KOMPSAT-2 image and historical air photos for Jora and Makwasinyi villages show places where land cover changed or remained stable (Figures

7 and 8). In Jora, the 1955 air photo confirms the early cultivation of black cotton soil at Ilenyi and its division as farm plots (Figure 7a). In contrast, the KOMPSAT-2 image shows a significant expansion of farm fields in the surrouding bushland. Also farms expanded along the Mwangeta river just below the main road (Figure 57b). The riparian vegatation is much more open on the KOMPSTAT image, which may be attributed to an expansion of farming, resource extraction, and/or change in water levels on the river. The road shown on the two images is the major road from Rukanga to Bungule, which is wider in 2010 due to an increase in transportation activities unlike in the past when it was used primarily as a footpath (Figure 7). A similar expansion of farming is shown by the photo comparison at *Godoma* in Makwasinyi (Figure 8). In contrast the erosional slopes to the north of the village are of similar size and land cover (Figure 8).

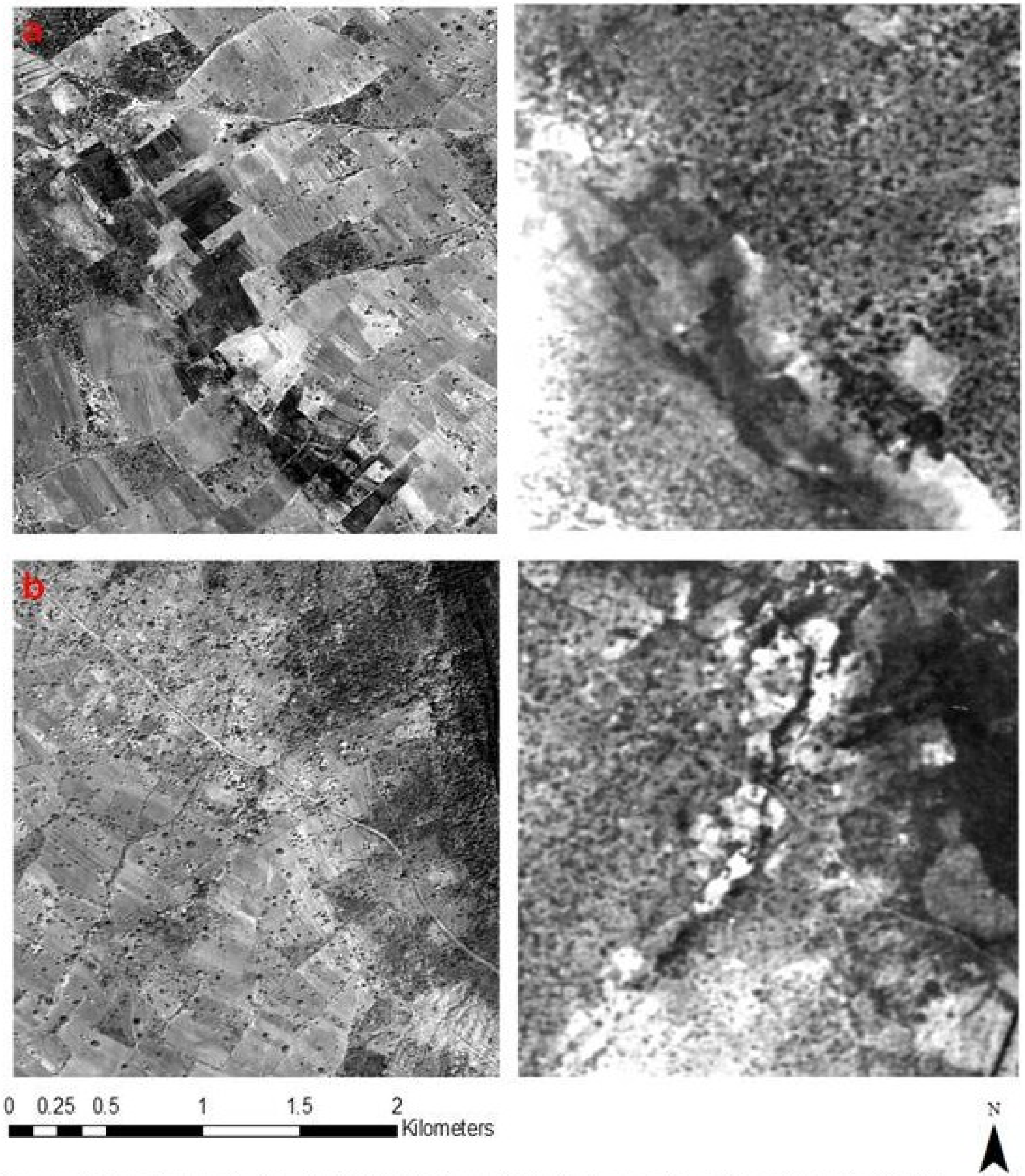

Figure 7. Land cover comparison for locations in Jora village between the 2010 KOMPSAT-2 image (left) and a 1955 air photo: a) cultivation on the black cotton soils. b) degradation of riparian vegetation along the Mwangeta river and the expansion and intensification of agriculture on the KOMPSAT-2 image.

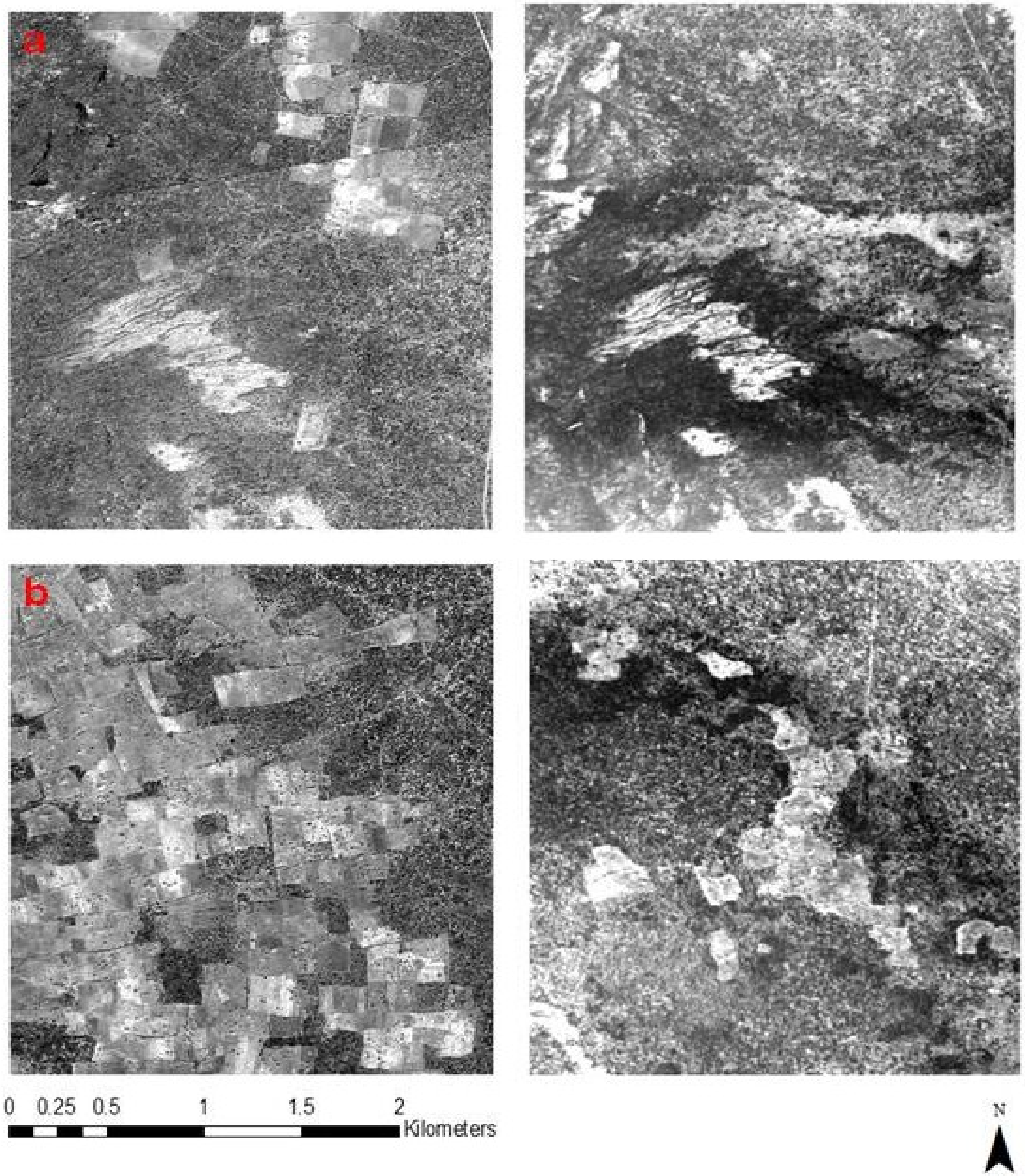

Figure 8. Land cover comparison for locations in Makwasinyi village in the 2010 KOMPSAT-2 image (left) and a 1957 air photo: a) erosional slopes north of the village that show open vegetation. b) expansion of farms at Godoma in the bushland.

How and Why has Land Cover Changed?

Focus Group Discussions following the Mapping Sessions

During the group discussions following the mapping sessions, the men and women participants highlighted several reasons for land cover/land use changes. The groups of men and women in Jora indicated that they originally lived in *Ndomokonyi* and farmed in *Kibutonyi, Mwakuri, Kwa Mununa, and Ilenyi* (Table 1). In Makwasinyi, the residents formerly lived in *Kijala cha Waka*, *Karima Ka Gona*, *Makanda*, and around *Mwajombo*. In both villages, the areas they lived in were adjacent to the farming areas and spread out along the mountain. However, in both villages, there were farms that were also located in the bushland. In Jora, *Ilenyi* is an area containing rich black cotton soil, while *Mkungonyi* and *Godoma* in Makwasinyi were bushland locations farmed in the past. Throughout the discussions in both villages, the residents stated that they previously cultivated crops such as sweet potatoes, maize, green grams, paw paws, sugarcane, millet, arrow roots, beans, cassava, peas, pepper, bananas, sorghum, pumpkins, and vegetables. Additionally, the residents in Jora and Makwasinyi were rearing cattle that stayed with them in their homesteads.

During the discussion sessions with the residents of Jora, the participants described that they began to shift downwards from the mountain in 1958 until the mid-1970's when they realized that their cattle were causing soil erosion within the areas they were living. According to the Jora men's group, the government authorities ordered the residents to shift from the mountain to the current settled area. In Makwasinyi, the group of men and women participants explained that they began to shift from the mountain in 1956 and 1959, respectively. Makwasinyi participants asserted that the major reason that made them shift from the mountain was the decreasing farm sizes and the rise in demand for more land for cultivation (Table 1). In addition to the reduction of farm sizes, the women's group in Makwasinyi described how the forested areas that surrounded their mountain farms contained wild animals such as wild pigs, eland antelopes, baboons, and vervet monkeys. These animals were invading their farms and destroying their crops, therefore, contributing to poor harvest (Table 1). The residents of Jora also farmed in *Ilenyi* and shopped in Mwatate. The crops harvested in *Ilenyi* and goods bought from Mwatate were transported uphill to their homesteads in *Ndomokonyi*. The difficulty in carrying luggage and harvested crops uphill was another causal factor that contributed to the downward movement of residents from the mountain as it was becoming tiresome to move up and down the mountain, especially for the old women (Table 1). The movement between the mountain and bushland farms (*Mkungonyi* and *Godoma*) also helped to explain the downward shift of Makwasinyi residents (Table 1). Jora participants further indicated that the expansion of family sizes coupled with a decrease in farm sizes available on the mountain and poor productivity contributed to the downward shift of residents from the mountain to the bushland.

The downward shift from the mountain of Jora and Makwasinyi residents played a significant role in changing the resources in these areas. Initially, Jora residents moved their cattle to the current settlement, which was a bushland that was inhabited by wild animals in the past. The wild animals that inhabited the bushland included baboons, antelope, buffalo, zebra, lions, elephants, dik-dik, and giraffes. These animals were a threat to their cattle and therefore, the boys in the village were tasked with the duty of grazing them during the day and returning the cattle to *Ndomokonyi* during the night (Table 1). Finally, the residents decided to shift permanently to the current settlement where they began clearing the bushland for cultivation and constructing a few houses; even the residents who were reluctant to shift followed eventually. This led to the migration of the wild animals deeper into the bushland. The shift in Makwasinyi progressed very slowly since some residents resisted relocating from the mountain. Families were shifting with their livestock and constructing homesteads in areas that were originally bushland before they began clearing new land areas for cultivation.

The downward shift in Jora and Makwasinyi led to the conversion of much bushland into farmland. As a result, several trees and shrubs in the bushland were cleared. Some of the species that were cleared included *Balanites aegyptiaca* (mwagani), *Acacia nilotica* (mchemeri), *Acacia brevispica* (taghasina), *Sclerocarya birrea* (mnyeshavua), *Terminalia prunoides* (mshogoreka), *Lannea scheweifurthii* (mshiga), *Manilkara mochisia* (mnao) *and Adonsonia digitata* (mlamba). The participants in both villages indicated that the conversion of the bushland into farmland began at the current settlement in Jora and around the shopping center in Makwasinyi, and then expanded to its current location across the bushland. As families expanded, more areas within the bushland were cleared for farms and the construction of homes. This contributed to land cover/ land use changes in areas that were previously bushland in both villages. Abandoned farms and settlements on the mountain, however, experienced vegetation regrowth and formed part of the woodland (Table 1). As a result, the men and women participants concluded that the major causal factors that stimulated land cover/land use changes was the downward movement of residents from the mountain coupled by an increase in population, which gave rise to greater demands for agricultural land.

In Jora and Makwasinyi, the participants further elaborated that the expansion of farms is continuing further into the surrounding bushland. For example, I documented farms on the 2010 KOMPSAT-2 image that were 2 km and 3 km from the village center at Jora and Makwasinyi, respectively. In Makwasinyi, the farms expanded from the old bushland farms (*Mkungonyi* and *Godoma*), while in Jora, farms expanded below the road toward *Itoronyi* and horizontally toward the boundaries with Rukanga and Bungule. While the residents agreed that the clearing of bushland for farms resulted in a decline in bushland trees, the residents also described the impacts of charcoal production on the availability of trees (Table 1). The residents noted that charcoal burning over the last 20 years contributed to a decline in specific tree species. Some of the tree species that have been cut for charcoal include: *Manilkara mochisia* (mnao), *Acacia etbaica* (shighire), *Ficus thonningii* (mvumu), *Terminalia brownia* (mkungo), and *Newtonia hildebrandtii* (mkame). The participants in Jora and Makwasinyi explained that charcoal burning by the Duruma from Buguta village and by Kamba from Ngambenyi were major threats to the remaining bushland (Table 1). Additionally, the men and women of Jora stated that in the last five years, Somali communities are invading the bushland with several herds of cattle, which have contributed to the decline in vegetation cover. Conclusively, the men and women of Jora and Makwasinyi argued that the changes in resources within the bushland are caused by clearing land for new farms, cutting trees (by Duruma and Kamba) for charcoal, and burning and continuous grazing of cattle by the Somalis and the residents (Table 1). Within the forest, the participants of both villages noted that in the last four years, the harvesting of sandalwood (Kijulu, *Osyris lanceolata*) on the mountain was a recent and the only major threat to the forest in the two villages (Table 1). However, they explained that the changing weather patterns are affecting vegetation cover. In the past, the vegetation was dense, but as a result of lack of sufficient rainfall, some of the trees and shrubs on the mountain have dried up, therefore making some areas bare (Table 1).

Table 1. Compiled narratives from the mapping participants on the causal factors of land cover and land use changes.

There were few people in the past who were living in Ndomokonyi. We lived in one place with our cattle and cultivated in Kifumbu and Ilenyi. When the population of cattle began to increase, the colonial government told us to build terraces in our farms. Later on, they ordered us to shift from the mountain because the cattle were causing soil erosion (Jora Men's group).

We initially shifted the cattle to the bushland. During the day time, the boys would graze them in the bushland and bring them back to Ndomokonyi at night because we feared the wild animals would attack them. However, when the boys started living with the cattle in the bushland, we would visit them each morning and find out how their night was, milk the cattle, and bring them food. This became tiresome and we decided to shift downward and that is when we began clearing the bush for farmland and constructing our houses (Jora Women's group).

The transportation of goods uphill that were bought from Mwatate and crops harvested from Ilenyi was tiresome especially for the old women. This motivated the community to shift to lower grounds (Jora Men's group).

In the past, there were few people living in Ndomokonyi, the farms were large, but when the population began to increase, the farms became smaller and some people decided to look for alternative farms in the bushland (Jora Women's group).

In the past, we cultivated on the mountain. The forest surrounding our farms contained some wild animals. These animals would attack our crops and therefore we decided to relocate to the current area (Makwasinyi Women's group).

We were farming in the bushland (Mkungonyi and Godoma), and the resident decided to move out of the mountain because we were wasting a lot of time, and it was becoming difficult to move up and down the mountain. A lot of residents were growing maize and as farms became smaller, the residents decided to look for alternative farms to grow their maize and that is why we decided to shift from the mountain (Makwasinyi Men's group).

Table 1 (continued).

The only reason we relocated from the mountain was the decreasing farm sizes. We moved away voluntarily and no one told us to shift from the mountain (Jora Men's group). *In the past, the bushland had a lot of trees. When people started farming in the bushland, they cleared the trees and burned them down. However, in the early 1990's, the Duruma's and Kamba's started cutting the trees for charcoal burning and sold it to middlemen who transported it to Mombasa (Jora Men's group).* *The Somalis have brought large herds of cattle that are making the bushland to be bare (Jora Men's group).* *A person from Tanzania came and told us that sandalwood (Kijulu) is highly priced. From that time, people started poaching it from the mountain (Jora Men's group).* *In the past, the mountain was extremely dense; the rocks were not visible as much as they are today because there was sufficient rainfall in the past (Jora Men's group).* *There are a lot of trees and shrubs in Ndomokonyi and Kifumbu. After the resident shifted, tree and shrubs seeds which were dormant began to germinate and grew into trees. It is very difficult for a person to differentiate areas we used to live and farms and the rest of the mountain (Jora Men's group).* *Originally, there were plenty tree in the bushland. The trees were cleared to pave way for new farms. As population increases, people began to clear more of the bushland for farms and some of the trees were cut down for charcoal, poles and firewood (Makwasinyi Women's group).* *In the past, the bushland was denser compared to how it is currently today. Charcoal burning by the Duruma's, cattle grazing and farming in the bushland has affected the area. Wild animals such as elephants, giraffes and others have migrated deeper into the park and when they lack food, they invade our farms because we have destroyed their habitat (Jora Men's group).*

I conducted a total of five transect walks across land cover types in Jora and Makwasinyi (Figure 9). Each walk differed in the number of participants (4-7 persons) but all included members from the larger groups that worked on the participatory maps (Table 2). Both women and men joined the transects except the two that were to evergreen forest at the top of the mountain (Nyangala and Ingire). Also, on the transect to the summit, I went with a mixed group that included men from Makwasinyi, my field assistant from Jora, and two guides from Kiteghe village.

Table 2: Transect walks completed with participants from Jora and Makwasinyi (Figure 9).

Code	Direction	No of Participants		Distance
		Men	Women	
A	From the Kiteghe-Makwasinyi road to the summit of the mountain (Nyangala	4	0	5 km
B	From Jora shopping center to Ingire (a proposed water source for Jora)	4	0	4 km
C	From Jora shopping center to the bushland at Itoronyi	5	2	5 km
D	From Makwasinyi shopping center-Makanda and Kijala cha Waka	3	1	2 km
E	From Makwasinyi shopping center to Lalakunyi in the bushland.	3	3	5 km

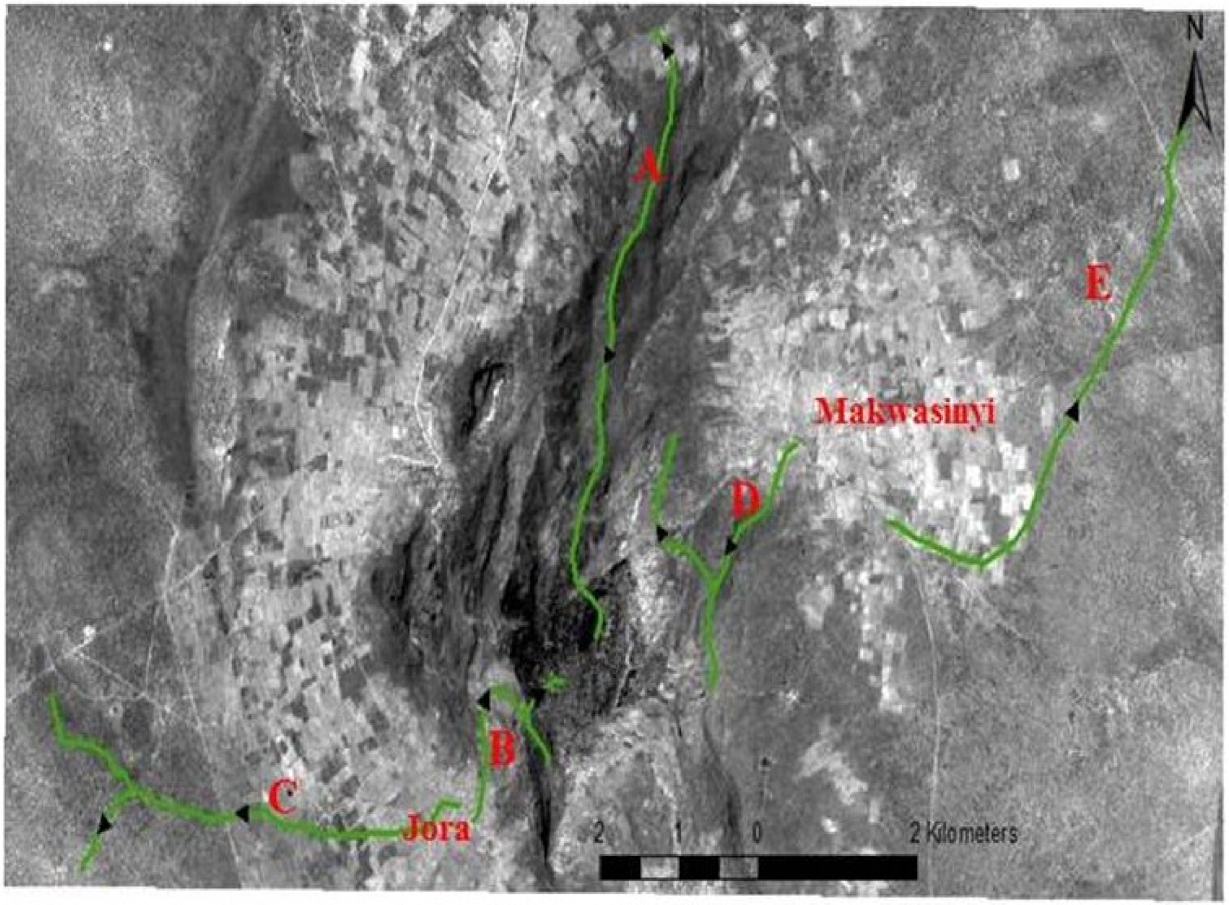

Figure 9. Transect walk approximate routes from Jora and Makwasinyi villages.

One transect walk from Jora (B) and one from Makwasinyi (A) climbed up the mountain to evergreen forest (Table 2; Figure 9) Along transect A to the summit of the mountain above Makwasinyi, we observed a closed dense forest, which participants described as having little changes except for the natural death of trees (see Figure 10a). During both walks in the evergreen forest, they said that these forests served as a water catchment for the location and therefore, the residents made sure that it was conserved. They described the collection of *kijulu* (*Osyris lanceolata*) as the only major threat to the montane forest. On our route to *Ingire* (Transect B, Figure 9*)*, we walked across a site where their ancestors conducted sacrifices during the dry seasons under one sacred tree. We saw clay pots that were used by their ancestors in a 'rain ceremony' that further declared the importance of the forest to the community. Afterwards, we walked across the forest up to the source of water at *Ingire*. Evergreen forest on the Bungule side appeared undisturbed and its protection, according to the participants, could be explained by the "roles" it served the community and its relative inaccessibility.

The transect walks across lower montane woodland in Makwasinyi and Jora villages, took us across historical farms at *Makanda* and *Kijala cha Waka in* Makwasinyi (Transect D) and to *Ndomokonyi* and *Kibutonyi* in Jora (Transect B; Figure 9). The residents described how these locations looked like in the past and highlighted land cover/land use changes at the former village locations. According to the residents, the historical farms occurred as areas that were mainly dominated by food crops, with few trees and an open canopy. The woodland canopy, where the residents had not farmed in the past, was more closed compared to the areas which were farmed. Along the Makwasinyi transect, we noted fruit trees such as mangoes, oranges, and pepper on a recently abandoned farm (Figure 10b). In Jora, the residents used to terrace their farms to prevent soil erosion and remains of stone terraces at *Kibutonyi* were clearly visible (Figure 10c). Additionally, Jora residents described *Ndomokonyi* as an area where the entire population lived in a village setting which was given its name after mdomoko (*Grewia tephrodermis*), which was and still is a common small tree in the area.

The transect participants acknowledged that land cover changes in the woodland began to occur when they shifted from the mountain farms to the bushland. During the walks, the former farms were not clearly visible because they had regenerated into woodland. The historical farms in both villages contained a lot of grass undergrowth that was dominated by *Ivondo* and *Lukoko* grasses in comparison to the rest of the woodland. One mfagio (broom-making) grass species, which dominated the montane forest, was now present in some sections. While traversing the two former villages, we observed a more open canopy woodland in areas that were farmed and settled in the past. Within the historical woodland, the canopy was much more closed compared to the historical farms. Most recently, the residents described the "poaching" of kijulu (*Osyris lanceolata*), where I was shown some branches in Jora village, but I was informed by the residents that the practice had decreased drastically after the species was cleared and some of the collectors were arrested (Figure 10d).

Across the bushland and current farmland in Jora and Makwasinyi, we traversed locations that had changed and areas that showed minimal changes (Transects C and E; Figure 9,

Table 1). The residents informed me that the current farms were dominated by *Acacia* species in the past, forming a contiguous bushland with wild animals. Farming expanded in the past and this expansion continues to impact bushland vegetation. They noted that the trees now absent from the farmland would still be found in bushland. The expansion of farmland was not viewed as an impact on resource availability. In contrast, the farmlands were enriched with introduced fruit trees (e.g., miembe- mango; mkorosho-cashew) and some shade trees (msaji- *Senna siamea*).

The transition from farmland to bushland is discontinuous and patchy. We saw sub-divided farms inside the bushland, and cleared bushland that was being converted into farmland Figure 10e). While walking across the areas that had changed in the bushland, the participants described the changes in relation to what the place looked like in the past. In Jora and Makwasinyi, I was informed that for the last 20 years, there has been an invasion of the bushland by the residents for farming purposes as the settlement population increased. The residents further explained that the changes occurring in the bushland were also caused by other factors such as grazing and charcoal burning. According to the residents, the invasion of the bushland for charcoal burning contributed greatly to the changes that we were currently observing. As we traversed in the bushland, we was able to see several spots that used to be charcoal kilns and new charcoal kilns, confirming the threats to the bushland from charcoal burning activities (Figure 10f). They mentioned a decline in some of the same trees, also mentioned during the group discussion sessions such as: shigire (*Acacia etbaica),* mkungo *(Terminalia brownii),* mchemeri *(Acacia nilotica), and* mbambara *(Commiphora campestris*).

These transects enabled me learn how and why land cover has changed in the two villages. First, the walks made it possible to collect local interpretations of land cover changes and local views on the causes of land cover changes or factors that were inhibiting changes. Secondly, these transect walks provided a ‘vertical’ view of how land practices in the past influence the current structure of the vegetation. Lastly, the transect walks provided a greater potential for validating local knowledge on land cover changes that can be used in proposing measures for natural resource management since the local communities understand the drivers and causes of land cover changes.

a) The montane forest where little change has occurred except for the natural death of trees in the mountain.	
b) A recently abandoned pepper farm in Makwasinyi, showing historical farms that have regenerated into woodland in the background.	
c) A photo showing stone terraces located in historical farms at *Kibutonyi* above Jora.	

Figure 10. photos showing land cover and land use changes that were describe during the transect walk in Jora and Makwasinyi

d) A photo showing twigs of kijulu (Oyris lanceolata) that has been cleared in Mt. Kasigau illegally.	
e) A photo showing new farms inside the existing bushland which is common in Jora and Makwasinyi.	
f) A recently built charcoal kiln showing destroyed woody acacia that are used for charcoal burning in Jora and Makwasinyi villages.	

Figure 10. Photos showing land cover and land use changes that were described during the transect walks in Jora and Makwasinyi.

Figure 10 (continued)

Chapter Six

DISCUSSION AND CONCLUSION

The purpose of this research was to investigate how the integration of remote sensing, geographical information system (GIS) techniques, and local knowledge can contribute toward understanding land cover changes at Mt. Kasigau. The research employed GIScience and qualitative techniques to examine *what*, *how* and *why* land cover has changed in Jora and Makwasinyi villages. Focal groups of men and women in Jora and Makwasinyi participated in local mapping sessions with the aim of mapping historical and current land cover types for their respective villages. Their maps show how land cover types have undergone diverse changes. Using these maps, I overlayed the historical and present land cover types and features for the two villages onto a KOMPSAT-2 1 m resolution panchromatic image for 2010. Local maps drawn by the focal groups of men and women in Jora and Makwasinyi show the spatial distribution of different past and present land cover types. The second research question focused on how and why land cover changed at Mt. Kasigau. In exploring this question, I carried out gender-sensitive group discussions with the mapping participants to understand the causal factors of land cover changes in the area. The discussions of how and why land cover has changed focused on their interpretation of the local maps they produced. I also carried out transect walks across land cover types that were mapped by the residents on their local maps and recorded narratives of land cover changes in the area. For this discussion, I highlight how local mapping knowledge can be integrated with GIScience to understand what, why and how land cover changes with the aim of sustainable management of natural resources.

Historical Perspectives Gained through Landscape Ethnoecology

The relation between human beings and nature is a complex phenomenon. Over the last few decades, there has been a growing interest in adapting an interdisplinary approach for studying complex relationships between human beings and their natural environment (Barrela-Bassols & Toledo 2005). Ethnoecology provides an integrative approach toward the investigation of relationships between human beings and the natural environment (Nazarea

1999). Specifically, ethnoecologists focus on the contributions of local knowledge and local perspectives on how human beings interact with the natural environment and how relationships change over time (Nazarea 1999).

Sustainable management of natural resources requires the integration of local and scientific knowledge. Ethnoecology supports problem solving in natural resource management by integrating indigenous knowledge with scientific knowledge (Rist & Dahdouh-Guebas 2006). The local community in Mt. Kasigau views their landscape differently. For example, during the local mapping sessions in Jora and Makwasinyi villages, the local residents perceived their landscape according to its cultural and natural significance. They did this by emphasizing place names and features that were important to the community. My study concurs with other ethoecological research that shows how local communities identify their landscape differently from the way 'scientists' describe landscapes. In a study done by Johnson (2000) among the Gitksan community in British Columbia, he found that the community perceptions and views about their landscape were different from how ecologists viewed their landscapes. In the research, he showed that the Gitksan community describes their landscape "by both the topographic features and the presence or absence of standing water and trees", unlike the scientific views, which perceive landscape according to the type of species identified and the geomorphic features identified (Johnson 2000). These findings are important for sustainable management of resources because local viewpoints seem to more directly relate to the historical significance of a place and its local potential. For instance, when engaging the community in natural resources conservation, issues concerning how and why land cover has changed may already be embedded in the distribution of named locations.

Agarwal (2001) further explains that perceptions about natural resources in a similar landscape also differ between men and women. In Jora and Makwasinyi village, the views of men and women showed differences when they explained why they shifted from the historical mountain farms. In Makwasinyi, the women's group lamented that one of the reasons they shifted from the mountain was that the forested areas surrounding their mountain farms contained wild animals that were invading their farms and destroying their crops, therefore, contributing to poor harvest. These reasons were not given by the men's group in the village which concurs with a previous research carried out in the same village, by Medley & Kalibo (2007), who found that there was a clear distinction between how men and women portrayed their landscape. In their research, they highlighted that women in Makwasinyi tended to enlarge the extent of their farms while compressing their landscape to show the relative places they collected firewood. Indeed, from this research it is clear that local communities have their own perceptions of their landscape. As a researcher, there is a need of understanding and incorporating those perspectives in land cover analyses.

Integration of Local Mapping Knowledge and GIScience

Participatory mapping entails the creation of maps by communities with the involvement of other stakeholders (Chambers 2006). During local mapping sessions, communities compile and plot spatial information, which is based on their perception about their areas (Bauer 2009). Participatory GIS integrates GIScience and local mapping toward gaining a perspective on local land cover that has both local and extra-local meaning (Dunn 2007). To understand how local mapping knowledge can contribute towards understanding land cover changes, I integrated the local maps drawn by the residents with high-resolution satellite image. I then realized that the local maps presented different types of knowledge that were absent from the image, especially in identifying places that are significantly important to the community. At the same time, the local residents had a difficult time distinguishing local land cover types on the satellite image or even portraying it on their local maps. In this study, I used participatory mapping sessions, focal group discussions, and transect walks to elaborate on the attributes of different land cover types and to record narratives on the perceived land cover/land use changes. Mixed methods were important toward gaining knowledge from the residents about land cover changes in the area and the information that was acquired from the community form an important contribution toward local resource management. The study provided a forum to integrate the concerns of local residents in the spatial analysis of land-cover change.

Opportunities and Challenges

The local residents in Makwasinyi and Jora mapped different land cover types and features, and named places that are important to their respective communities. These land cover types and features were easily geo-referenced onto the KOMPSAT-2 image. Additionally, some of the place names that were described and identified by the residents were recognized in the KOMPSAT-2 image. The participatory maps showed greater details about some land cover changes compared to the current KOMPSAT-2 image. For example, the residents mapped several footpaths and rocky areas, which were difficult to see in the KOMPSAT-2 image. This finding concurs with other participatory research that shows how participatory maps can reveal greater details on land cover changes than satellite images (Mapedza et al. 2003). In the study done by Mapedza et al. (2003) at Mafungautsi forest in Zimbabwe, the researchers found that participatory maps revealed greater details about the causes and timing of land cover/ land uses changes. However, the challenges of integrating local knowledge and GIScience have been underscored by other researchers (Mbile et al. 2003). During the local mapping session with the groups of men and women in Jora and Makwasinyi villages, residents would not always agree on some issues, especially the placement of features on their local maps. Consensus then becomes a challenge for the integration of GIScience and participatory mapping. Dunn et al. (1997) noticed that some participants overrule others since they may be forced to accept the perception of highly regarded community members who are leaders in the society although their knowledge might not be true.

Ultimately in this study, I argue the importance of integrating local knowledge and GIScience in sustainable management of natural resources. Results that were obtained from the field show that the communities possess much knowledge about the causal factors of land cover/land use changes. Without this knowledge, conservation measures might not be well-received or yield effective results. By integrating local and scientific knowledge, outsiders are able to learn for the community, hence enabling opportunities to exchange ideas and jointly gain skills in resource management (Nethengwe 2007).

Although the study emphasizes the importance of integrating local knowledge and GIScience, I discovered that the residents were reluctant to use the KOMPSAT-2 image as a base map for mapping their landscape. They expressed problems visualizing and interpreting images taken from the air and its spatial resolution. They had difficulties distinguishing land cover types such as the woodland and the montane forest, an important purpose in remote sensing analysis, because they viewed landscapes as a mosaic of different places that had current and/or historical meaning. However, the KOMPSAT-2 image was extremely helpful when using it with the air photos in determining prominent locations of land cover change. Therefore, future studies using satellite images and air photos should focus on training residents on how to interpret and visualize air borne images, and exploring different image types, prior to embarking on a mapping exercise.

Conclusion

In this study, I conclude that conservation strategies in resource management should assimilate local knowledge that communities possess. First, researchers should understand that local communities play an important role in resource management with the local knowledge they possess. Secondly, it is the role of researchers to integrate the local knowledge in resource management since policy makers tend to ignore local knowledge in proposing measures for natural resources management. This study further elaborates on the land cover/land use changes that have occurred in Jora and Makwasinyi villages, especially on what has changed, and why and how those changes have occurred. From the study, I conclude that the major land cover/land use changes were the conversion of bushland into farms and former farms into woodland. Farms expanded due to an increase in population in the area, and trees and shrubs in the bushland are being extracted for charcoal by migrants to the region, according to the local residents. Additionally the study found that the upper montane evergreen forest was one of the areas that showed minimal changes due to its cultural and natural importance to the community. Finally, I come to the general conclusion that the integration of local and scientific knowledge is important in natural resources management since problems in resource conservation requires local solutions rather than imposing solutions to the residents who are aware of the causes of land cover/ land use changes in their area.

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Appendices

Appendix I

MIAMI UNIVERSITY
OXFORD OHIO

Office for the Advancement of
Research and Scholarship
102 Roudebush Hall
Oxford, OH 45011
513-529-3600

Date: May 23, 2011

To: Mr. Njoroge Ikonye Gathongo, Geography
Mr. Kimberly Medley, Geography

From: Dr. Leonard S. Mark, Chair
Institutional Review Board for Human Subjects Research

Re: Human Subjects Project titled:
Validating Local Interpretations of Landscape Change at Mt. Kasigau, Kenya

Thank you for submitting the above-referenced protocol to the Institutional Review Board for Human Subjects Research along with the requested documentation. The committee has reviewed and approved your proposal as Expedited Status.

Your proposal approval number is: 11-167

Approval of this project is in effect until: May 21, 2012

If you complete your project before the date listed above, please send an email to humansubjects@muohio.edu that your project is complete and we will close your file.

Should you decide to change your procedures relating to the use of human subjects in the above project, you must obtain approval from the Committee **prior** to instituting any changes.

Miami University policy requires periodic review of human subjects for all ongoing projects. If your project will continue beyond the approval date mentioned above, you will need to submit an Application for Continuing Review so that the committee may review your application in a timely fashion.

Please submit your next application for continuing review by: April 21, 2012

On behalf of the committee and the University, I thank you for your efforts to conduct your research in compliance with the federal regulations that have been established for the protection of human subjects. Thank you for your attention to this matter, and best wishes for the success of your project.

11-167

Appendix II

REPUBLIC OF KENYA

NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

Telegrams: "SCIENCETECH", Nairobi
Telephone: 254-020-241349, 2213102
254-020-310571, 2213123.
Fax: 254-020-2213215, 318245, 318249
When replying please quote

P.O. Box 30623-00100
NAIROBI-KENYA
Website: www.ncst.go.ke

Our Ref:
NCST/RRI/12/1/SS-011/889/4

Date:
7th July, 2011

Njoroge Ikonye Gathongo
Miami University
Office of the Advancement of
Research and Scholarship
102 Roudebush Hall
Oxford, OH 45011
513-529-3600
USA

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on **"Validating local interpretations of land cover changes at Mt. Kasigau, Kenya"** I am pleased to inform you that you have been authorized to undertake research **in Taita Taveta District** for a period ending ***31st August, 2011.***

You are advised to report to **the District Agricultural Officer, the District Commissioner, the District Forest Officer, the District Education Officer Taita Taveta District** before embarking on the research project.

On completion of the research, you are expected to submit **one hard copy and one soft copy** of the research report/thesis to our office.

SAID HUSSEIN
FOR: SECRETARY/CEO

Copy to:
The District Agricultural Officer
Taita Taveta District

Appendix III

Places	Description
Jora	
Cairo	✓ Farming and settlement area
Bawawi	✓ Grazing land
Ngambenyi	✓ Kamba village and area where livestock are kept. ✓ Site for future farms expansion.
Ndomokonyi	✓ Historical settlement
Mwangondi, Mkongo, Kwa Mashaka, Kwa Luka, and Kibutonyi.	✓ Historical farming areas that have regenerated into bushland.
Mkongo, Sangambunyi, Kwa Mashaka, Mwangeta, Mwasungita, and Mwashindi	✓ Locations along the river Mwangeta named after the people who lived there.
Mwakuri	✓ Farming and settlement
Kifumbu	✓ Village settlement in jora-Around Ndomokonyi.
Kwa munana	✓ Current and historical farms in Jora
	✓
Mghongo Ghwa Mbisi	✓ Large rock in Jora located near the boundary with Bungule village.
Ilenyi	✓ Area with the black cotton soil, currently and historically farmed.
Viriwenyi	✓ Location in the woodland on the northern part of the mountain.
Jogolo	✓ A dam in the bushland.
Mwandolo	✓ A cave located northest of Jora village.
Ding’ ding’	✓ A rock outcrop located on the western part of the village

Itoronyi	✓ Bushland used for grazing and exploited for charcoal by the Wakamba's and Duruma. ✓ Area where fuel wood and building materials are harvested
Ingire forest	✓ Contains a shrine used by rainmakers (rain tree). ✓ The forest is also a water catchment area.
Makwasinyi	
Lalakunyi, Gondoma, and Mkungonyi	✓ Historical and current farming places. Farms have expanded along these areas.
Tombolo and kirongwe	✓ Settlement and farmlands located north of the central village.
Isume	✓ Location deep inside the forest and below the peak of the mountain and serves as a water catchment area.
Mwakasau	✓ Places located within the woodland and bordering Bungule.
Mavore	✓ Location along the edges of the woodland and the farms near the shopping center in Makwasinyi
Makanda	✓ Historical farms and settlement in Makwasinyi.
Mkufinyi	✓ Water intake point for the village.
Kigondika, Kijala Cha Waka, Ndiwa, Karima Ka Gona and Mwajombo.	✓ Historical settlement and farming areas.
Ikurungunyi, Igweja fuwe and Karima-Ka-Gona	✓ Exposed rocky areas containing sparsely distributed vegetation cover within the woodland.
Ndiwa, Mwerinyi, and Kwanzia	✓ Locations along the river Kamwandugi named after the people who lived there.
Nyangala	✓ The mountain rock summit that does not have

	vegetation
Ilao, Mwakambata, Ngombenyi, Mzuzinyi, Kivuta Mbeo, Malombo, and Ribe	✓ Historical farms that have regenerated into woodland.
Mkandanga, *Mjindu, Ndashinyi, Iriwa jakoba, Mwangenyi, Koba and Mkungo*	✓ Water holding points in the bushland-excavated by elephants.
Kamwandugi	✓ A stream originating from Mkufinyi in Makwasinyi village.
Places	**Description**
Jora	
Cairo	✓ Farming and settlement area
Bawawi	✓ Grazing land
Ngambenyi	✓ Kamba village and area where livestock are kept. ✓ Site for future farms expansion.
Ndomokonyi	✓ Historical settlement
Mwangondi, Mkongo, Kwa Mashaka, , Kwa Luka, and Kibotonyi.	✓ Historical farming areas that have regenerated into bushland.
Mkongo, Sangambunyi, Kwa Mashaka, Mwangeta, Mwasungita, and Mwashindi	✓ Locations along the river Mwangeta named after the people who lived there.
Mwakuri	✓ Farming and settlement
Ilenyi	✓ Area with the black cotton soil, currently and historically farmed.
Itoronyi	✓ Bushland used for grazing and exploited for charcoal by the Wakamba's and Duruma. ✓ Area where fuel wood and building materials are

	harvested
Ingire forest	✓ Contains a shrine used by rainmakers (rain tree). ✓ The forest is also a water catchment area.
Makwasinyi	
Lalakunyi, Ngondoma, and Mkungonyi	✓ Historical and current farming places. Farms have expanded along these areas.
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Ikurungunyi, Igweja fuwe and Karima-Ka-Gona	✓ Exposed rocky areas containing sparsely distributed vegetation cover within the woodland.
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Ilao, Mwakambata, Ngombenyi, Mzuzinyi, Kivuta Mbeo, Malombo, and Ribe	✓ Historical farms that have regenerated into woodland.