



**UNIVERSITY OF NAIROBI
SCHOOL OF ENGINEERING**

DEPARTMENT OF GEOSPATIAL AND SPACE TECHNOLOGY

**ASSESSING CONTRIBUTION OF SACRED NATURAL SITES TO CLIMATE
CHANGE EFFECTS ON DRYLAND ECOSYSTEM
CASE STUDY: THE GABBRA COMMUNITY, MARSABIT COUNTY**

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A project report submitted in partial fulfillment for the Degree of Master Of Science in Geographical Information Systems, in the Department of Geospatial and Space Technology of the University of Nairobi.

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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ABSTRACT

Sacred Natural Sites are features that occur naturally in different spatial locations and are holy to a specific group of people. They are found in different forms for example rocks, sacred groves, mountains and other naturally occurring features. This study focused on sacred groves which are a group of sacred trees mainly the remnants of natural forests. A database was created containing the different sacred sites found among the Indigenous community by the name Gabbra found in Marsabit County. Sacred groves act as primary network of conservation spots harboring biodiversity that cannot be found in the entire ecosystem. In this era when forest cover has reduced significantly globally, they remain the only spots that indigenous biodiversity is found. Indigenous biodiversity can withstand adverse climatical events for example droughts and famines hence being the only source of resilience especially in the dry land ecosystems of Kenya.

This study used Normalized Difference Vegetation Index (NDVI) to ground truth if indeed the sacred groves provide resilience in the midst of adverse droughts. Landsat data was used dating 30 years back to study if the sacred groves conserved biodiversity since the community considers area where the groves are found holy preventing the encroachment of the trees found in the sacred groves. A database of other sites was made and applied to make analysis that made the investigation of the contribution of sacred sites to climate change resilience possible.

The results from land cover classification and change detection showed that even after massive deforestation happened in Hurri Hills, the sacred grove remained intact and the NDVI remained high throughout all years for example the following years 1973, 1984, 1995, recorded values of 0.2941, 0.5288, and 0.6602 respectively. The trees and other biodiversity in that area have remained intact hence conserving the species that once were found in the forests that have been degraded. When the ecosystem experiences drought, the trees and the biodiversity in the groves replenish the Gabbra Community and their animals.

DEDICATION

To my family and friends for their love, care and support during my studies at the University of Nairobi.

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LIST OF ACRONYMS

CGOM	County Government of Marsabit
ETM	Enhanced Thematic Mapper
GUI	General User Interface
GOK	Government of Kenya
GPS	Global Positioning System
IPCC	Intergovernmental Panel on Climate Change
NDMA	National Drought Management Authority
NDVI	Normalized Difference Vegetation Index
NRVI	Normalized Ratio Vegetation Index
OLI	Operational Land Imager
SAVI	Soil Adjusted Vegetation index

CHAPTER 1.0: INTRODUCTION

1.1 Background

Sacred Natural sites are defined as natural features or areas of land and water that have spiritual significance to a specific group of people (Verschuuren et al, 2010). All over the world they occur in form of different features and scales for example pilgrimage routes, waterfalls, a single rock, tree, springs, entire mountain range, lakes, forest patches and caves. Rutte (2011) and Schelhas, and Greenberg (1996) note that different authors have their own definition of forest patches regardless of where they occur. Trees in sacred patches may occur in pastures, as a line of trees along the rivers as well as large fragments in the main forest. Forest patches may exist together and these aid in managing natural resources. However, sacred patches must be under the custodian of the community and values, beliefs and practices must be attached to them.

Sacred natural sites that belong to the indigenous and local communities are considered more valuable than those belonging to the mainstream religions. In India, sacred groves are found in many parts and many of these are those that are inhabited by the indigenous communities (Khan et al, 2008). Indigenous communities have a deep sacred connection to nature and localized belief systems are attached to the sites (Wild and McLeod, 2008). Khan et al (2008) notes that every sacred natural site has its own unique myths, lore and legends attached to it and this makes it distinct. Sacred groves refer to virgin forest patches which are characterized by rich indigenous biodiversity and maintained by the local people for centuries. Deep taboos, cultural and religious beliefs are attached to them because the deities reside in the forest patches to protect the indigenous communities from adverse calamities (Khan et al, 2008).

Conservation of natural reserves and plants has been an integral part of cultural norms, especially with the indigenous communities. As part of nature worship, conservation was among the rituals which connected the communities with their ancestors, gods, divinities and spirits hence a spiritual relationship with their biophysical environment (Paper, 2001). The sacredness attached to the sacred groves ensures the preservation of some important indigenous biodiversity which is able to withstand adverse climatic conditions. The fact that only elders are allowed to visit the sacred groves play a very important role in the conservation of biodiversity. In India, Gadgil and Vartak (1976) noted that any collection of even dead twigs from the sacred groves is considered a taboo.

Globally, climate change is an important environmental problem whose effects adversely impact on indigenous communities living in all ecosystems (Bharali and Khan, 2011). Climate change impacts in the dryland are felt intensely because the ecosystem is already more stressed. UNDP and UNCCD (2009) states that Africa is made up of 43% dryland where 325 million people live (Fraser et al, 2011).The population mainly depends on the natural resources as their only source of livelihood.

Impacts of climate change that mainly affect this dependence include the disappearance of biodiversity that the indigenous communities rely on for food, medicine, pasture and others used as tools for their cultural and religious practices also referred to as the ecosystem services (MEA, 2005). In realization of this important fact, global guidelines have in the past been recommended by the International Union for the Conservation of Nature and UNESCO to help in the management of sacred groves.

The guidelines are in support of many follow up conventions and policies that have arisen as a result of the Rio Earth Summit in 1992 that highlighted the role of indigenous knowledge in the conservation of biodiversity as a way of ensuring climate change resilience of communities (Mauro and Hardison, 2000). Sacred groves found in the dryland ecosystem, link human livelihood systems and the ecosystem functions hence a justification to biodiversity conservation and proper environmental management. Different ecosystem services which include regulating, provisioning, cultural and supporting services emanate from the sacred groves (Ghazoul, 2007 and MEA, 2005). Therefore, this acts as a constant reminder that the achievement of the Sustainable Development Goals 2015 needs to be closely related to the valuation of Ecosystem services that should be led by the indigenous communities through involvement in initiatives at the grassroots level (Corrigan and Eddie, 2013). Climate change effects regulation is one of the ecosystem services provided by the sacred groves. Carbon is one of the main causes of climate change in that, once it is released into the atmosphere, it forms a blanket around the earth hence causing global warming. Sacred groves are forest tracts where there is no human interference in form of deforestation thus the vegetation is intact.

Regional climate is affected by deforestation in that it reduces carbon sequestration which in turn causes a rise in temperature (Bharali and Khan, 2011).The vegetation which is comprised of trees and other vegetation types acts as carbon sinks because of its ability to take in carbon and reserve it. In dryland ecosystems, the indigenous vegetation is well adapted to the local conditions

(Lenyasunya & Wanyama, 2009). In this era when climate change effects are being adversely felt, such vegetation act as a source of resilience and an indicator for the potential of the natural vegetation (Schaaf, 1998). Indigenous vegetation present in the sacred groves are free of human interference and encroachment hence provide resilience even when the rest of altered vegetation is affected by drought.

Therefore, a very close link between climate, the natural ecosystems and the socio-cultural aspects of the indigenous communities living in the dry land ecosystem is formed. Sacred groves of the dryland ecosystem are the converging point of the three aspects due to the functions they provide to the indigenous communities. Sacred groves are responsible for the provisioning of fresh water and food. Direct Access to food and fresh water from sacred groves may not be possible due to the belief that the deities reside in them hence prompting only the elders at special times to visit them. However, sacred groves are sources of rivers and streams that can be accessed by members of the community downstream. Kenya's Hurri Hills in Marsabit is an example of this scenario. Rivers have their source here making the cultural landscape a water tower that has a national significance. Birds and other mammals have their home in the sacred groves.

1.2 Problem Statement

Sacred groves have for a long time been protected hence low levels of disturbance which has made them rich biodiversity hotspots. They provide the community with ecosystem services which include protecting and regulating sources of cultural and spiritual wellbeing (Veerschuren et al, 2010). A dry land ecosystem is vulnerable to climate change effects which lead to a shortage in the supply of the ecosystem services (Dougill et al, 2010). These effects include drought which is worsened by anthropogenic activities like fire wood harvesting and overgrazing. Drought in the dryland ecosystem is severe because of indigenous communities heavy reliance upon natural resources hence their vulnerability to adverse climate change effects (Nakashima et al, 2012).

According to DFID (2004), climate change is likely to aggravate the indigenous communities vulnerability to drought-related issues and will even worsen their ability to recover or cope with the shocks brought about by climate change. Sacred natural sites contribution to climate change is, therefore, important if the climate change effects resilience is to be achieved.

1.3 Objectives

1.3.1 Main Objective

To assess the contribution of sacred groves to climate change on dryland ecosystem using the Gabbra Community as a case study.

1.3.2 Specific Objectives

- a. To review the characteristics of sacred natural sites.
- b. To identify the spatial dimensions of the sacred natural sites.
- c. To develop a database for the sacred natural sites.
- d. To apply the database in order to assess the contribution of sacred natural sites to climate change in the dry land ecosystem.

1.4 Justification for the Study

This research is important to researchers at the universities and research institutions that are seeking to relate the emerging disciplines namely culture, climate change and conservation. It is also important to anthropologists and any party interested in knowledge on how bio-cultural research can contribute to climate change resilience. The National Environmental Management Authority can use the research to control developments around places that are of cultural significance.

1.5 Scope of work

This study is limited to how the sacred natural sites have acted as a tool for the ecological and social resilience of the dryland ecosystem to effects of climate change. This study was done at Hurri Hills, Marsabit County which is mostly occupied by the Gabbra Community.

1.6 Organization of Report

The report is organized systematically in 5 chapters. Chapter one is the introduction which is made up of the background, a problem statement, the objectives, a justification and the scope of work. Chapter two is Literature review while chapter three deals with methodology and materials. Results and discussion are outlined in chapter four. Chapter five deals with conclusions and recommendations. The references follow thereafter.

CHAPTER 2.0: LITERATURE REVIEW

2.1 State of Forests as a Biodiversity Reserve

Forests act as the main carbon reserves, stabilize climate and cover 31% of the earth's surface which translates to over 4 billion hectares. In the preindustrial era, forest cover was 5.9 billion hectares (Lasco et al, 2004). The world's largest forest cover loss happened in 1990 when a total of 16 million hectares was lost each year due to major drivers, one of them being agriculture.

Notwithstanding this, some areas gained forest cover through natural regeneration and planting of forests bringing the total forest net loss to a total of 8.3 million hectares per year (Lasco et al, 2004). Ecological resilience against climate change effects is provided mainly by biodiversity. Since forests are the main reserves of biodiversity, there is a concern globally to save the remaining forest cover. Africa is the second leading continent in forest cover loss which translates to a massive biodiversity loss (FAO, 2008). Main causes of forest loss in the continent include forest fires which are mostly caused by the anthropogenic conversion of forest land to agricultural land through the traditional means mostly burning (Kissinger et al, 2012). A net forest cover loss of 4 million hectares per year from 2000 to 2005 occurred in Africa This is an indicator of massive biodiversity losses translating to a total of 655.6 million hectares (ha) to 635.4 million ha during those epochs (FAO, 2008). According to FAO, Kenya's natural forest cover has reduced overtime as tabulated in Table 2.1.

Table 2.1: Kenya's forest loss over time

Category of forest resource (using FAO definitions)	Area ('000 Ha)				Annual change
	1990	2000	2005	2010	1990 to 2010
Indigenous closed Canopy	1240	1,190	1,165	1,140	-5
Indigenous Mangroves	80	80	80	80	0
Open woodlands	2,150	2,100	2,075	2,050	-5
Public Plantation Forests	170	134	119	107	-3.15
Private Plantation forests	68	78	83	90	+1.1
Sub-total Forest land (total of above categories)	3,708	3,582	2,357	3,467	-12.05
Bush-land	24,800	24,635	24,570	24,510	-14.5
Farms with Trees	9,420	10,020	10,320	10,385	+48.25
Total Area of Kenya	58,037	58,037	58,037	58,037	0

Source, Ruri (2013)

Biodiversity loss is hence massive and the only reserves remaining that contain the indigenous biodiversity are the sacred groves. These well-preserved patches are storehouses for plants and other biodiversity, therefore, acting as the refuge to threatened species (Anthwal et al, 2006). Forest loss in Kenyan rangelands is caused by overgrazing in the forest areas, charcoal burning, and illegal logging as well as agricultural expansion (Ruri, 2013). In Marsabit, Mt Marsabit forest area covers approximately 15,700 hectares (Ruri, 2013). Over the years, forest cover has reduced as a result of agricultural expansion and grass land expansion which has overshadowed the natural forests. In 1985, the total forest cover was 240.5km² and reduced to 132km² in 2010. The total grassland area in 1985 was 592 km² which expanded to 665 km² in 2010.

Cropland increased by half from 66 km² to 93km² by 2010 according to a report by Ruri (2013). Marsabit town has overtime expanded encroaching into the forest further degenerating biodiversity. Illegal firewood collection and grazing in the forest has not spared the biodiversity and neither has large scale charcoal burning. A total number of 50,000 cattle graze in the forest according to the report by (Kissinger et al, 2012). All the mentioned causes of forest loss in Marsabit can be termed as direct causes of forest cover which have led to massive biodiversity loss. To further demonstrate the total forest cover that has been lost in Marsabit from 1985, Table 2.2 demonstrates this scenario by indicating the other land uses which have been the main culprits for the forest loss.

Table 2.2: Other land uses that have contributed to forest loss in Marsabit from 1985 - 2005

CHANGE 1985 – 2005 in km ²						
	Cropland	Forestland	Grassland	Other land	Settlements	Wetland
Cropland	61.0745	0.1087	2.1806	0	2.4752	0
Forestland	28.4869	132.044	79.0494	0	0.6968	0.189
Grassland	8.3951	0.9123	582.4358	0	0.663	0
Other land	0	0	1.7923	0	0	0
Settlements	0.3316	0.0024	0	0	3.4462	0
Wetland	0	0	0.2677	0	0	0.4307

Source, Ruri (2013)

All the stated land uses have hindered regeneration of forest cover in Mt. Marsabit forest ecosystem. Although the area is a dryland ecosystem, migration of pastoralists to the area has enhanced the transition to a permanent grazing area. This has aggravated vegetation loss exerting

extra pressure on the already strained dryland ecosystem which depends solely on biodiversity for ecological resilience.

2.2 Characteristics of Sacred Groves that can be Monitored by Remote Sensing

Different characteristics of sacred natural sites determine whether it is possible for remote sensing methods to be used effectively to monitor changes in a cultural landscape. According to Khan et al, (2008), sacred groves are characterized by a group of trees which are considered sacred. By use of vegetation indices, the group of trees can be monitored to determine their status over time.

Normalized Difference Vegetation Index (NDVI) can be used to monitor the health and the status of the sacred groves especially due to logging and fire (Böttcher et al, 2009). The fact that trees in sacred groves can be spatially referenced and have chlorophyll makes them suitable for remote sensing techniques application which goes a long way to aid in their conservation as well as rehabilitation.

2.3 Sacred Groves in India and North America

The role of sacred groves has recently been attracting attention due to their role in the conservation of biodiversity which in turn enhances resilience against climate change effects. According to Hughes and Chandran (1998), they are parts of a cultural landscape which contain trees and various biodiversity in form of plants and animals and are protected by human societies as an expression of a close relationship with the deities that are believed to reside in them. India has, so far, the highest number of reported sacred groves totaling to thirteen thousand, seven hundred and twenty (Malhotra et al, 2001).

Different religious and cultural celebrations and rituals take place in sacred groves and none of the plant species is harvested except in the event of a disease whereby only special community members get the herbs for medical purposes only (Sambandan and Dhatchanamoorthy, 2012). In addition, exchange of Traditional Ecological Knowledge also takes place in the sacred groves (Gadgil et al. 1993, Berkes et al. 1995). Gadgil et al. (1993) and Berkes et al. (1995) define Traditional Ecological Knowledge as a body of knowledge, belief and practice that is cumulative and continuously evolves through adapting to different dynamics that face a community over the course of years, for example, a changing climate.

Traditional Ecological Knowledge is handed down from one generation to another through cultural transmission teaching younger generations how human beings should relate to their environment for peaceful coexistence and continuity in resource use (Gadgil et al, 1993, Berkes et al, 1995). In the recent times, Verschuuren et al, (2010), notes that religious systems and Indigenous communities need to adapt their cultural and religious controls to ever-changing global dynamics like developments and climatical variations to avoid massive losses of cultural and biological diversity. In India, many sacred groves are remnants cut out from forests (Sambandan and Dhatchanamoorthy, 2012). Some tribes in most remote hilly areas depend fully on forests for forest resources. This leads to conserving massive numbers of wild plant and animal species through religious and cultural practices (Khan, 2003).

The attitude towards these forests supports their conservation while developmental dynamics and change of attitudes towards the forests is also a major cause of degradation. This is leading to losses of different rich varieties of biodiversity (Khan, 2003). Sacred groves remain untouched due to the sacred aspect attached to them and this makes them rich reserves of biodiversity which is intertwined with various aspects of religious, cultural, and indigenous practices as well as taboos that are attached to the sacred groves (Khan et al, 2008; Garg, 2013). As it is the case for most sacred groves, whenever they exist, indigenous traditional societies sustain them because of the spiritual relationship between them and the physical environment (Khan et al, 2008; Gaisseau, 1954). A study done by Balasubramanyan and Induchoodan (1996) in Kerala, India, recorded a total number of 761 sacred groves. The sacred groves were found to harbor over 722 species of floristic diversity belonging to 217 families and 474 genera. Another study done by Sunitha and Rao (1999) demonstrates the diverse distribution of biodiversity richness in the sacred groves in Kurnool, Andhra Pradesh, India. Here, a single sacred grove extending over 72,681m² harbors a total number of 106 species.

Anthwal et al (2006) note that industrialization is among the factors causing degradation of sacred groves as well as overpopulation. There is a growing need for infrastructural development hence the reason for a decline in the total number of sacred groves in India.

Subsequently, pollution, introduction of exotic species, habitat alteration, overexploitation and climate change are taking a toll on global biodiversity reserves. Sacred groves remain one of the most notable biodiversity reserves amidst such threats (Anthwal et al, 2006). A study by Chandrashekara and Sankar (1998) highlights Nagoni Sacred forest as having a higher species

richness as compared to non-sacred parts of the forest as well as non-sacred forests. Tripathi et al (2006) conducted a study on forest fragmentation in Meghalaya, Northeastern India where he studied biodiversity richness and regeneration of tree species.

In the study, smaller fragments represented sacred groves and larger ones were other parts of the forests which were not sacred. In the sacred groves, (Tripathi et al, 2006) noted faster regeneration of species and rare and endemic species as compared to the larger fragments. From this study, a conclusion can thus be made that smaller fragments that have been made sacred are more diverse in biodiversity and climate-related stress is well dealt with in the sacred grove. This is because resilience in terms of regeneration can be experienced due to presence of indigenous biodiversity which can withstand climatic shocks for example drought. In North America, sacred groves exist among the Navajo who are also known as the Indigenous Indian people. According to Lebbie and Freudenberg (1996) the Navajo set aside places in forests such as areas reserved for herbs collection, mountain tops, old home sites, burial grounds as well as trees that were struck by lightning and home lodges. Destroying these places through logging would lead to destruction of the spiritual values attached to them (Schelhas and Greenberg, 1996). The Navajo have four ranges that are sacred and they mark the Dinétah boundaries which are known to be the homeland to the Navajo as well as the sacred cosmos.

In the South-Western Boundary, the San Francisco Peaks represent the dwelling place of the Navajo Spirits and they signify the body of their god. Environmental elements like the rocks, earth, plants and trees represent the skin of their god. Herbs are collected from the skin of their god and they use them for healing purposes. Environmental rules that the Indians possess regarding how man should relate to the land are relevant to the current problems that are being faced by the society, for example, adverse climatical conditions like drought. If incorporated into the current American legal system, they may be resourceful in building resilience to the population that is mainly affected by the adverse climatical events like drought (Ward, 1992).

Currently, the Indian territories have been repossessed by the central government since many of the sacred sites are on federal land. For this reason, degradation of the forest resources is being experienced due to the relaxed rules on the governance of the forest and environmental resources.

Indian people believe that the natural state of the sacred places must remain intact or else they lose the sacred aspect that is attached to them. Ceremonies that are conducted at these places

might be disrupted by any alteration of the landscape or any use of the same since it is believed that the sense of isolation associated with such sacred places may be interfered with hence driving away the spirits that live in the sacred sites (Ward, 1992).

2.3.1 Sacred Groves in Africa

In Africa, rural communities have set aside wooded patches that survive due to strong religious and cultural forces. Access to these patches is restricted hence making them distinct from the surrounding agricultural and grazing area (Sheridan, 2009). Sacred groves are rich in diverse biodiversity since they are vestiges of the indigenous forests that have not been altered by human interference. Sacred groves form a network of conservation islands of remnant indigenous biodiversity that are intertwined with traditional knowledge and cultural or religious rules and practices (Mgumia and Oba, 2003; Verschuuren et al, 2010). Different communities have appointed powerful members who safeguard the sacred patches by punishing anyone who extracts resources from the sacred groves or trees (Freudenberger, 1993). Any unauthorized access to the sacred trees is punishable due to the spirits, deities or other bodies that are supernatural that reside in them (Bharali and Khan, 2011). Very few studies have been done focusing on the sacred groves of Africa and their biodiversity conservation capacity in terms of the total number of species existing or almost extinct. Freudenberger (1993) ; Gerden and Mtallo (1990) and Dorm-Adzobu et al (1991) note that sacred trees and sacred groves belong to Islam and Christian communities.

Sacred groves in Sierra Leone were first discovered by European explorers who first visited the coast and noted the rituals people performed in the sacred forests which were located near their villages (Schelhas and Greenberg, 1996). Researchers and administrators in the precolonial period studied the communities that used to conduct their religious practices around mountains, streams, springs and mountain tops (Gaisseau, 1954; Schelhas and Greenberg, 1996). In Sierra Leone, men and women have their own sacred groves where they conduct different rituals and different decisions are made.

Poro is men's association and it controls the fishing grounds, palm harvesting and other environmental resources while women's association is known as Sande. Poro and Sande have their sacred forests where the spirits, deities and their gods are said to exist (Van Beek et al, 2011; (Schelhas and Greenberg, 1996). Hale is a type of medicine that controls good and bad and

it is invoked whenever any decision concerning the resources needs to be made. Proper behavior towards the natural resources is enforced by Hale hence regulating any misuse and extraction of the indigenous biodiversity existing in the sacred forests (Lebbie and Freudenberg, 1996; (Schelhas and Greenberg, 1996). The colonial administration in the early days noted that the tradition of the Poro placing their signs near the sacred forests restricted any trade and extraction of the biodiversity which has led to diminishing forest resources and even extinction of the same (Schelhas and Greenberg, 1996). Men cannot enter the sacred groves that belong to women unless on special occasions for example when women do not have the physical strength to conduct the practices associated with the sacred groves (Schelhas and Greenberg, 1996). Some of these rituals include burying the dead women who die when giving birth. If the women cannot dig the graves due to lack of physical strength men enter the sacred patches and they help out. However, some rituals must be performed to the men after that (Schelhas and Greenberg, 1996). The Sande Sacred Forests are store houses for a very wide variety of plant species used for medicinal purposes. As revealed by herbalists, some of the herbs can only thrive in mature Sande Forests and no hunting or gathering is allowed in the forests. The Sande forests are one or two hectares in size and are noted to be more prevalent compared to the Poros (Lebbie and Guries, 1995). Therefore different genders approach sacred groves differently based on the ceremonies and festivals that take place in the Poros and the Sandes. Ghana has a total number of 1,900 sacred groves (Ntiamoah-Baidu, 1995; Ormsby, 2013). Sacred groves are commonly referred to as fetish groves in Ghana and they serve a special purpose, unlike others. The fetish groves serve as burial ground or shrines (Amoako-Atta 1995; Gaisseau, 1954).

In Tanzania, sacred forests total up to 920 and their sizes between 0.125 and 200 ha. The sacred forests are found in the Handeni District and North Pare Mountains as well as Tanga region of Tanzania. In North Pare Mountains, in the last 20 years, population pressure has increased to 60% and this has resulted in demand for forest products shooting up tremendously (Mwihomeke et al, 1998). Serious punishments were imposed on anyone who damaged the sacred forests and it was more serious as compared to a person being taken to a modern court of law (Sheridan, 2009). Mgumia (2003) and Lebbie and Guries (1995) highlight the significance of the sacred forests to the national economy and even to the health sector where health facilities are far away and the only source of medicine is the sacred forests.

In Kenya, the Kaya forests are sacred among the Mijikenda found at the Kenyan Coast. Kayas are part of coastal forests that extend from Zanzibar hence the name Zanzibar-Inhambane lowland Mosaic (Burgess and Clarke, 2000; Kibet and Nyamweru 2008; Nyamweru, 1996). The forest region is rich in species level exhibiting a rarity of biodiversity. The coastal forests are the remnants of the coastal closed forest cover estimated to be about 67000 ha (Burgess and Clarke, 2000).

About 5% of the remaining coastal forests are found in the Kayas which translates to very high numbers of species diversity. The Kayas are a perfect example of how knowledge, attitudes and practices have shaped a landscape for a long time enhancing biodiversity conservation (Kibet and Nyamweru, 2008). The Kayas contribute immensely to climate change effects mitigation in several ways which include providing herbs which are used to make medicine to cure illnesses that are caused by the climate change at the coast (Groh, 2016). They are also rich reserves for biodiversity besides providing different ecosystem services (Matiku, 2005). Different weather extremes experienced in the climate change era are regulated by the Kayas. Genes are reserved in the forest patches that belong to the indigenous plants that can withstand harsh climatic changes (Wekesa et al, 2016).

Kaya forests support the local adaptation to climate change effects which enhance resilience by reserving the rich genetic resources. The genetic resources are used by the locals to improve crop cultivars by use of wild species and the known varieties which strengthen the known varieties making them adapt to the changing climatic conditions (Swiderska et al, 2011; Wekesa et al, 2016). When combined together, genes from the wild and the known variety form new varieties which are better suited for the new conditions. The local communities improve the varieties creating better crops which can resist pests and diseases better, produce more yields as well as resist drought more than their relatives (Wekesa et al, 2016). In the face of climate change, wild crops are ideal for their nutritional benefits and their high resistance to pests and diseases.

Therefore, Kayas have an ideal opportunity to preserve high-level crop diversity that is important in warding off emerging diseases and pests as well as the never-ending drought cycle hence improving agricultural production. By domesticating the wild crops, the communities have gained in that their ability to diversify their livelihood is also enhanced (Wekesa et al, 2016; Kibet, 2011). Kaya sacred forests are out of bounds to community members. Elders are the only people allowed into the forests to carry out their duties and responsibilities (Nyamweru, 1996;

Nyamweru, 1998). Rules are different for the individual forest patches meaning every clan has their own protocol and procedures on how their sacred forests should be accessed (Khan et al., 2008). The enforcement of the rules indicates the community's desire and will to conserve biodiversity as a way to ensure sustainability of the ecosystem services that emanate from the cultural landscape (Githitho, 2005).

Despite sacred forest patches having the above-discussed benefits and more, they are faced with different threats which include ignoring the traditional knowledge system. The younger generation is disregarding the traditional knowledge system that has been used by the elders in the past to conserve the Kaya (Oviedo and Jeanrenaud, 2007). Therefore, this cultural change accounts as an internal force that is a major threat facing the Kayas. Hence it compromises on the cohesiveness of the traditional values of the locals which has in turn caused the abandonment of the rules and acts that enhanced conservation of biodiversity in the sacred forests (Wekesa et al, 2016).

As urbanization happens, the younger generation is moving into cities hence staying away from the elders from whom they should learn the traditional ecological knowledge. The modern schooling system which keeps the younger generation away from the villages is also a factor that is contributing to loss of the traditional ecological knowledge by inhibiting the elders from passing it on to the younger generation (Wekesa et al, 2016). As time passes and the Kaya elders die they do not pass the traditional ecological knowledge to the younger generations hence disintegration between generations occur affecting social cohesion and causing social dislocation. Respect for traditional cultural values is eroded making the sacred forests conservation to be seriously threatened almost at the face of extinction (Wekesa et al, 2016; Sheridan, 2009).

Climate change effects adaptation is thus affected hence little or no resilience happens, in turn, leaving the community exposed to the adverse climatic events for example droughts, diseases and pests, famine as well as floods. The change is like a chain reaction which finally impacts on the community members who become vulnerable to the extreme climatic events. Overexploitation of the Kaya Forests is another problem threatening the sacred forests in turn wreck havoc on the extreme climatic effects resilience of the community. Medicinal herbs whose harvesting is allowed from the Kaya forests are being overharvested for commercial

purposes thus straining the provisioning of the ecosystem services. Pressure has increased more with the harvesting of fruit, food and construction material (Van Beek et al, 2011).

Some herbs which were used for medicinal purposes are on the verge of extinction if caution is not taken to prevent this tragedy. Herbs that have become so rare in the sacred forests include *Dalbergia melanoxylon*, *Manilkara sansibarensis*, *Brachylaena huillensis*, *Brachystegia spiciformis*, *Azela aquanzensis*, and *Vepris glometar*. Owing to overexploitation their natural distribution is declining at a very fast rate. Some fruits have also been on the decline risking the community's food security status (Wekesa et al, 2016). Unsustainable land uses practice is a major threat to the Kayas due to the declining cash crop production. The Mijikenda community is hence looking for more farm land to increase the cultivation of their two major cash crops namely cashew nuts and coconut (Mutta et al, 2009). Some of the cited causes of low production of these cash crops include the recurrent droughts and unreliable rainfall patterns. As a way of livelihood diversification, the Mijikenda have come up with other income generating activities that are environmentally unsustainable (Wekesa et al, 2016).

Rabai Kayas have been mostly affected by these unsustainable activities which include harvesting of poles for building purposes, farmland clearing as well as sand harvesting (Kibet, 2011). As these unsustainable activities go on, important agrobiodiversity which are used by the community to improve the genetic makeup of the known crops continue to disappear. This hence impacts negatively on the food security of the Mijikenda Community by reducing their adaptive capacity to climate change effects hence their resilience is affected as well (Wekesa et al, 2016). It has also been noted that degradation of the Kaya forests has led to the disappearance of ponds and springs within the forests. This shortcoming coupled with the recurrent drought periods makes women more vulnerable to the extreme climatic events since they have to travel long distances in search of water.

According to the 2009 population census (Republic of Kenya, 2009), Coastal area was noted to be among some of the areas where population growth rate and development is occurring at a very fast rate. These two factors are also contributing to the degradation of Kayas (Muli, 2016).

Ongugo et al (2014) state that in the last 20 years forest encroachment has increased by 45%. This has also been driven by subsiding agricultural production due to droughts, emerging pests and diseases that are as a result of climate variations. The sacred natural sites found in Gabbra's

territory are as outlined in the Table 2.3 below in form of trees and hills. Spatially, they are found in Hurri Hills area and Forolle which are near the Kenyan-Ethiopian border.

Table 2.3:Gabbra Sacred Sites

Sacred Natural Site	Form	Location
Gada Mata Barchuma	Sacred Hill	Forolle
Mukheggu	Sacred Grove group of trees	Hurri Hills
Elnadeni	Sacred Hill	Forolle
Burarat	Sacred Hill	Forolle
Qalqach Gandile	Sacred Grove	Forolle

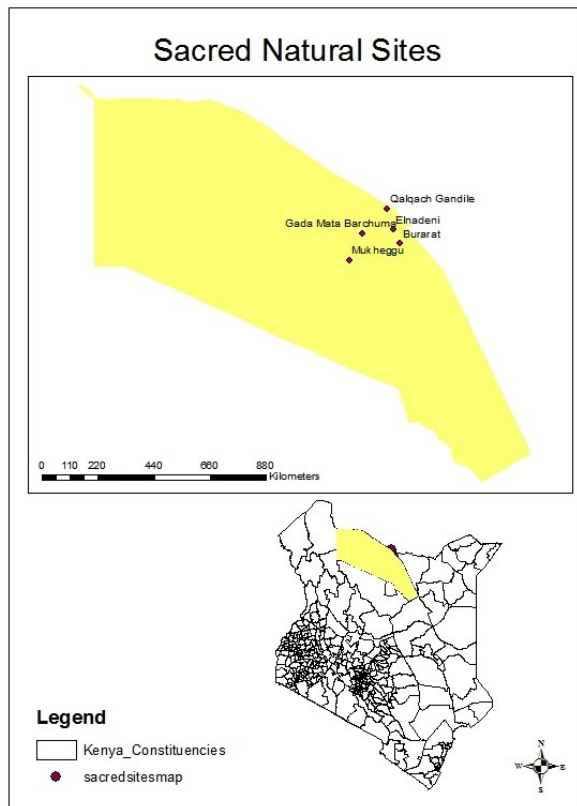


Figure 2.1: Sacred Natural Sites Location

2.4 Definition of Drought

In this study, drought is defined based on the Intergovernmental Panel for Climate Change (IPCC) definitions and classifications of drought types. According to IPCC (2014), drought

refers to dry weather that runs for a period of time that is long enough to cause any imbalance in the hydrological cycle. Drought is classified according to the type of activity affected by its occurrence. For example, agricultural drought is associated with inadequate precipitation that impacts on ecosystem services and the growing season. Soil moisture is normally affected by this abnormally dry condition (IPCC, 2014).

Kenya has two seasons the short rain season and the long rain seasons. Any rainfall failure in either of the seasons could indicate droughts since it will most likely impact on agriculture or even the ecosystem services provided by the different types of ecosystems found in the country.

The long rain season mainly occurs in the March, April and May season hence giving this season a name by MAM. Short rain season occurs during the October, November and December season hence giving that season a name by OND.

According to Orindi et al, (2007), in Kenya two-thirds of the country and especially the areas around the Northern part of the country receive rainfall that is less than 500 mm per year. Therefore, these areas are classified as Arid and Semiarid Land. Every decade, Kenya experiences a major drought while minor droughts are felt after every three to four years (Orindi et al, 2007). A report by Oxfam International has recorded some of the worst droughts Kenya has experienced in the past and more recent ones as outlined in Table 2.4.

Table 2.4:Drought occurrence in Kenya

Year	Type of disaster Area of coverage (No. of people affected in the country)
2004–2006	Drought Widespread 3.5 million
1999/2000	Drought Widespread 4.4 million
1995/96	Drought Widespread 1.4 million
1991/92	Drought Arid/semi-arid zones 1.5 million
1983/84	Drought Widespread 200,000
1980	Drought Widespread 40,000
1977	Drought Widespread 20,000
1975	Drought Widespread 16,000
1971	Drought Widespread

Source, Oxfam International (2006)

However, in the arid northern part, drought is experienced regularly with varied consequences. In recent years, critical drought periods in the country were experienced in 1984, 1995, 2000 and 2005/2006 (UNEP/GoK, 2000). The impacts of these droughts on the population are increasing exponentially. Sacred groves have a role in combatting recurring droughts which is one of the indicators of climate change. The well-preserved biodiversity that exists in the groves provides food during extreme drought periods since the indigenous biodiversity is able to tolerate the drought.

CHAPTER 3: METHODOLOGY AND MATERIALS

3.1 Introduction

After poor short rains of 2016, the National Drought Management Authority (NDMA) predicted that 2017 was going to be a drought year. In the ASALS the total number of people likely to be affected by this drought has risen from 1.3 million to 2.7 million. This is a representation of 20% of the population in the pastoral areas (NDMA, 2017). Marsabit County is one of the nine counties that NDMA has listed that will severely suffer from deteriorating drought effects (NDMA, 2017).

3.2 Study Area

3.2.1 Position and Size

Marsabit County is the second largest county in Kenya after Turkana covering an area of 70,961.3km² which accounts for 11% of the country's total surface area. Located at the extreme part of Northern Kenya, it borders Wajir County to the East, Ethiopia to the North and North East, Lake Turkana to the west and North West, Samburu to the South and South West. Fig 3.1 Shows the location of Hurri Hills.

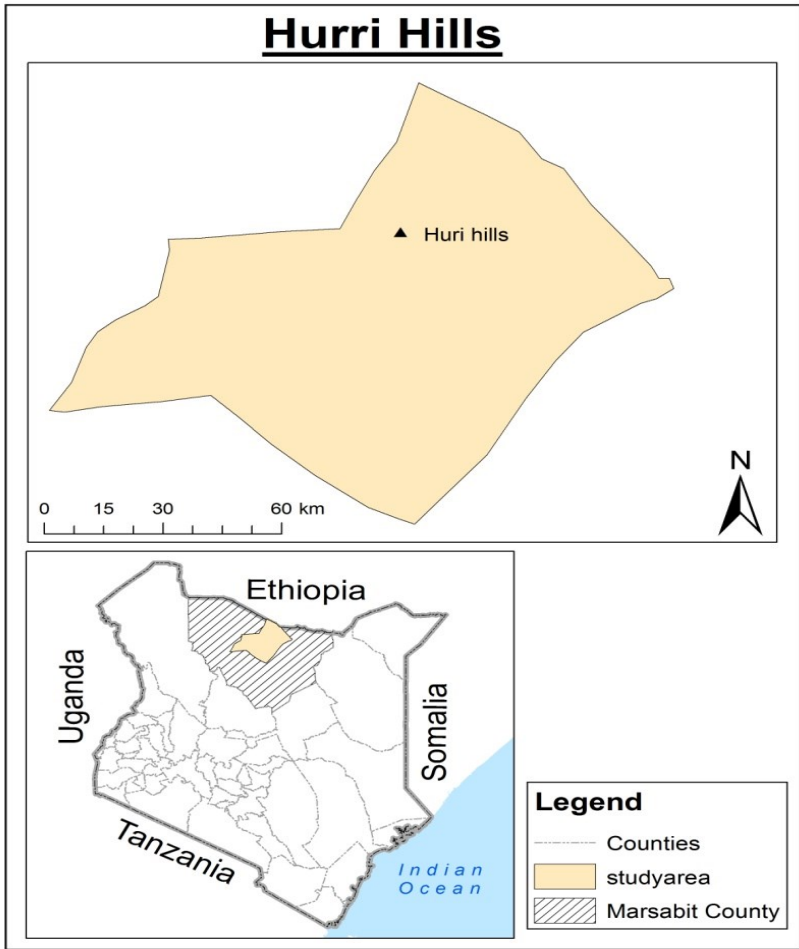


Figure 3.1: Location map of the study area

According to the 2009 Population Census, the recorded population was 291,166 (52% Male and 48% Female). This translates to 4 persons per km². Marsabit County is made up of seven sub-counties which include Laisamis, Maikona, Central Marsabit, Gadamoji and North Horr (CGOM, 2013). It lies between latitudes 02° 45' North and 04° 27' North and longitudes 37° 57' East and 39° 21' East (Mude et al, 2007). Hurri Hills and Mt. Kulal are located in the Northern Plains.

3.2.2 Climate

The climate of Marsabit is a dryland ecosystem with high potential areas around Moyale-Sololo escarpment, Hurri Hills, Mt Kulal and Mt Marsabit. It is characterized by temperatures ranging from a minimum of 10.1⁰ C to a maximum of 30.2⁰ C with an annual temperature range of 20.1⁰C. Annual rainfall averages between 200mm to 1000mm (CGOM, 2013).

Most parts of the county are arid, with the exception of high potential areas around Mt. Marsabit such as Kulal, Hurri Hills and the Moyale-Sololo escarpment. The amount of rainfall and duration as well as reliability is directly proportional to the altitude. Mt. Kulal and Mt Marsabit receive annual rainfall of 800mm while North Horr receives annual rainfall of 150mm. Moyale's mean rainfall annually is 700mm (Mude et al, 2007).

3.2.3 Physical and Topographic Features

Marsabit is mostly a plain area which gently slopes towards the southeast and lies between 300m and 900m above the mean sea level. Mountain ranges and hills border the County to the north and west while calderas volcanic cones constitute the geology of the County (Mude et al, 2007). In the South West, Ol Donyo Ranges which are 2066m above mean sea level is the most prominent topographical feature. Mt Marsabit which is 1865m above mean sea level is found in Marsabit Central while Hurri Hills which is 1685m above mean sea level is located in the North Eastern part of the County (CGOM, 2013). In the North West, lies Mt Kulal which is 2235m above mean sea level. Finally in the North East lies the mountains around Sololo- Moyale escarpment which measure up to 1400m above mean sea level (CGOM, 2013).

Chalbi desert is found in Marsabit County and it covers a large depression area of 948 km². Chalbi desert depression lies between 435 m and 500m above mean sea level. A ridge that rises to 700m separates Lake Turkana from the depression (Mude et al, 2007). Seasonal rivers are found in the County and form the main drainage system that covers an area of 948 km².

The most notable seasonal rivers which drain into the Sori Adio Swamp include Milgis and Merille found in the extreme south and flow eastwards. The largest drainage system is Chalbi desert. Other drainage systems found in the County include Dida Galgallu plains which receive run-off from the eastern slopes of Lake Turkana and Hurri hills and into which seasonal rivers Nyiru and Kulal drain.

The run-off from the surrounding basement surfaces of Mt. Kulal, Hurri Hills, Mt. Marsabit Ethiopian plateau and Mt. Kulal the surrounding lava drain into the depression (Mude et al, 2007).

3.2.4 Geological Conditions

Volcanic rocks are the most dominant geological formation in Marsabit County which extends both eastwards and westwards from the eastern part of the Rift Valley to the Ethiopian Border (Kaeser et al, 2006). Few areas of these volcanic rocks are interrupted by pockets of quaternary sediments and Mozambique belt (Mude et al, 2007; Kaeser et al, 2006; CGOM, 2013; Kaeser, 2006). Other varieties of geological formations include the old lake beds of Lake Chalbi and Turkana. Old, metamorphic rock of Precambrian origin are found underground in the south western and north eastern parts of the County (Kaeser et al, 2006; Kaeser, 2006).

In the north eastern and central parts and mostly the volcanic centers of Hurri Hills, Mt. Marsabit and Mt. Kulal, there exist Pleistocene and tertiary sheets and cones of volcanic rock (Kaeser et al, 2006; CGOM, 2013).

3.2.5 Ecological Conditions and Land Use

Marsabit County has two gazetted tropical rain forests namely Mt. Marsabit which covers a total area of 15,280 ha and Mt. Kulal biosphere conservation with a total area of about 45,729 ha. Marsabit is mostly a pastolist area. Hurri Hills are classified as wood lands which are managed by the County Council of Marsabit (Schlee, 1991). Low potential range land makes up about 75% of the total area which is also found 700m above sea level. This area is also characterized by low unreliable rainfall as well as high rates of evaporation hence making the soils in the region shallow and poor (Mude et al, 2007).

Areas that receive moderate rainfall of about 700mm annually include those at the foot of mountains namely slopes of Huri Hills, the middle slope of Mt. Kulal and Moyale Sololo escarpment. The plains of Bure Dera, Milgis, Dida Galgallu and Kaisut are also classified as moderate rainfall zones (Mude et al, 2007). In such areas, moderate rainfall of about 700mm annually is received. Major economic activities in this region include crop and livestock production. Main crops grown include beans, maize, millet, sorghum, vegetables and fruits (Munyao, 2005). Highland areas receive moderate rainfall and they have productive agricultural soils include Mt. Kulal, Ol Donyo Mara Range and Mt. Marsabit.

3.3 Methodology Overview

Two methodologies were used in this study each addressing the objectives. Specifically, the following methodology was used in the study; creation of database by storing the preprocessed images and applying the database to make different analysis which informed the study if resilience emerged from the sacred natural sites after a drought happened. The flow chart shown in Figure 3.2 outlines the different methodologies used.

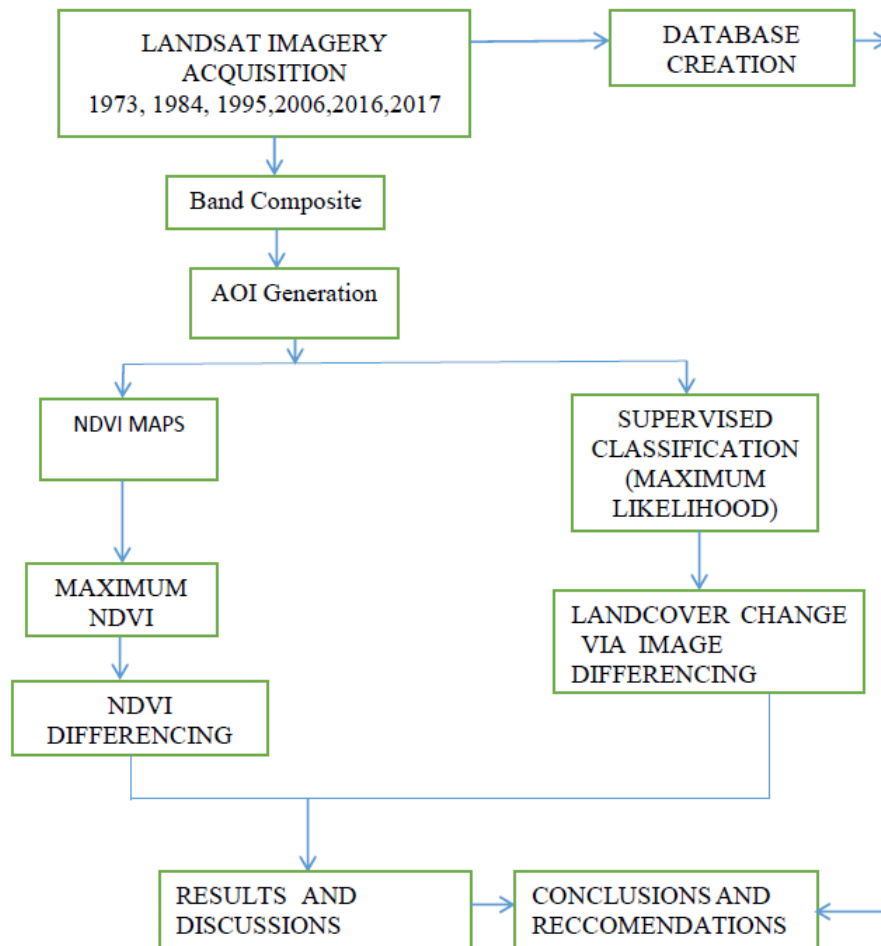


Figure 3.2 Methodology flow chart

3.4 Data Sources and Tools

3.4.1 Data Sources

Table 3.1 shows the type of data, used and the source.

Table 3.1:Data Sources

Data	Use	Source
Landsat Imagery	Landuse map generation	http://glovis.usgs.gov/
Coordinates	To geographically locate the sacred sites	Kivulini, Field data collection
Administrative boundaries	Delineate the study area	http://data.ilri.org/geoportal/
Sacred Sites coordinates	Map the spatial extent of the sacred sites	Field work, Kivulini Trust
Interview data	Get the knowledge, attitude and practices surrounding the sacred natural sites	Field work through questionnaires, interviews, Kivulini trust

(i) Primary Data

Primary data was collected from the community, institutions and from the responsible authorities in Hurri Hills area through administering questionnaires and interviews. The data was also obtained through direct observation and photographs taken in the field. Coordinates were picked in the field using a GPS handheld receiver.

(ii) Secondary Data

Secondary data was obtained from already recorded literature both published and unpublished materials, peer-reviewed journals, reports, newsletters, books, and records. Landsat imagery was obtained from the USGS glovis site. Landsat MSS data was used for the year 1973. In 1984, the thematic mapper was used while enhanced thematic mapper data was used for 1995 and 2006. The 2016 and 2017 Landsat data was acquired from Operational Land Imager which is the most recent and more superior than the predecessors.

3.4.2 Tools

Questionnaires were administered to the area residents who were selected randomly. Officials from the relevant institutions mainly non-governmental institutions and even government office were interviewed. Questionnaires were constructed to meet the objectives of the study in order to obtain information on the contribution of sacred natural sites to climate change in the dry land ecosystem. Direct observation was done to identify the status of the sacred natural site. Face to face interviews were conducted with the relevant local authorities in the area in-order to get more information. A GPS receiver was used to collect coordinates in the field as well as a camera to document the records which were observed. Different softwares were utilized in the study for data processing. They include ERDASIMAGINE 2013 which was mainly used for satellite imagery preprocessing. Image analysis was performed using ArcMap 10.4 where maps were generated and analyzed.

3.5 Data Processing

Images for years 1973, 1984, 1995, 2006, 2016 which were used had geometric distortions since images taken by satellites are likely to be subject to systematic and nonsystematic distortions. Systematic errors were corrected by analyzing the ephemeris and the characteristics of the sensor. Errors that were nonsystematic underwent geometric rectification of the satellite imagery. The years were selected based on the fact that all of them were drought years (Jensen, 1999). Geometric correction was performed by carefully selecting well distributed points on the ground as well as image pixel coordinates which had column and row numbers with their latitude and longitude (Jensen, 1999). To determine the coordinate transformation function equations coefficients, least square regression analysis was used. Resampling was used to interpolate the brightness value of the Landsat Images after the transformation function was produced. Orthorectification was performed to Universal Transversal Mercator (UTM) and had 0.5 pixel root mean square accuracy (RMS). Geometric correction was performed to remove the objects which were outside the focus of interest (Jensen, 1999).

Bands 321 were utilized for the 1973 and 1984 Landsat Imagery. Bands 432 were used for the 1995 and 2006 imagery while band 543 was utilized for 2016 and 2017 years. For the 2006 image, the sensors were faulty and hence the images were stripped. Destripping was therefore important to fill in the data gaps where the sensor did not pick the image parts. It was performed

through Focal Analysis tool in ERDAS 2013 (Jensen, 1999; Imagine, 2013).The images were layer stacked in ERDAS 2013 by using the layer stacking tool. The area of study was generated using the sub location shape file for each year.

3.5.1 Image Analysis

Image analysis was performed in ArcMap 10.4 was done through supervised classification. There are several analysis methods which include segmentation and unsupervised classification among others. In this study, supervised classification was appropriate for several reasons which include the advantage of controlling all the classes chosen. Supervised is based on maximum likelihood which operates on the assumption that the calculations or the statistics that are represented class in each band are distributed and the probability that a specific pixel belongs to a specific class is calculated. The class that has the highest probability is assigned each pixel (Jensen, 1999). Training sites were chosen which refer to the points that represent a particular land cover. Spectral signatures of each of the training sites depend on the material covering the region of interest (ROI). Training sites were picked depending on all the land cover type that was present in the landscape. Finally, supervised classification is more accurate as compared to other methods of remote sensing data analysis.

3.5.2 Image Interpretation

Image interpretation was done based on the following aspects; location, colour, pattern, size, tone, shadow and texture. Four classes were thus generated out of the following interpretation namely, shrub land, bare rock, bare soil and forest. Landcover around the sacred natural site was interpreted to determine if they have over the time been affected by drought.

3.5.3 Change detection

Change detection for all the years of selection was performed after image interpretation. In this study accurate and timely change detection of the land cover surrounding the sacred natural site was important for better decision making. The rate of forest cover change was relevant in this study as it assisted in knowing the conservation status in Hurri Hills. It also shed light on whether the sacred natural site has been degraded over time and if any urgent measure needs to be taken. In this study image differencing was used which involves subtracting the first year

image from the second date image pixel by pixel. Its advantage includes the fact that it is simple and straight forward which in this case was necessary in this study because of limited time (Mas, 1999). The results can be easily interpreted as compared to other change detection methods. However, the disadvantage of the method is that it could not provide a detailed matrix for change and it required thresholds of selection (Lu et.al, 2004).

3.6 Validation

Validation was performed using three different methods namely accuracy assessment, observations and interviews that were conducted on the community. Accuracy assessment was conducted in accuracy assessment tool in ERDAS IMAGINE 2013. Random stratified sampling which involved placing randomly a number of observations in each of the four categories of land cover was used (Mas, 1999).

3.7 Database Creation

In this study, database was created by building up on the initial data which was mainly the satellite imagery (Silberschatz and Sudarshan, 1997). Every stage of preprocessing produced data that was highly valuable because it was processed as compared to the previous data from which it was generated. Data that was stored in the cultural database included georeferenced images of all Landsat bands for all the years. All maps namely NDVI, land cover and land cover change were fed into the database. Database creation addressed the challenge that the study faced when gathering data from the field. The organizations that provided coordinates data faced a challenge in data retrieval and storage.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Results

4.1.1 Introduction

This chapter presents the results that were achieved from the methods that were used to analyze the dynamics surrounding the sacred natural site. The results from NDVI maps, land cover classification and land cover change maps are stated in this chapter. Discussion of the results is also included in the chapter.

4.2 Normalized Difference Vegetation Index

NDVI maps for all years namely January 1973, August 1984, January 1995, January 2006, January 2016 and January 2017 were generated as shown in Figure 4.1 whereby the low NDVI and high was indicated by the color ramp variance high being shown by the red part and low by the green part.

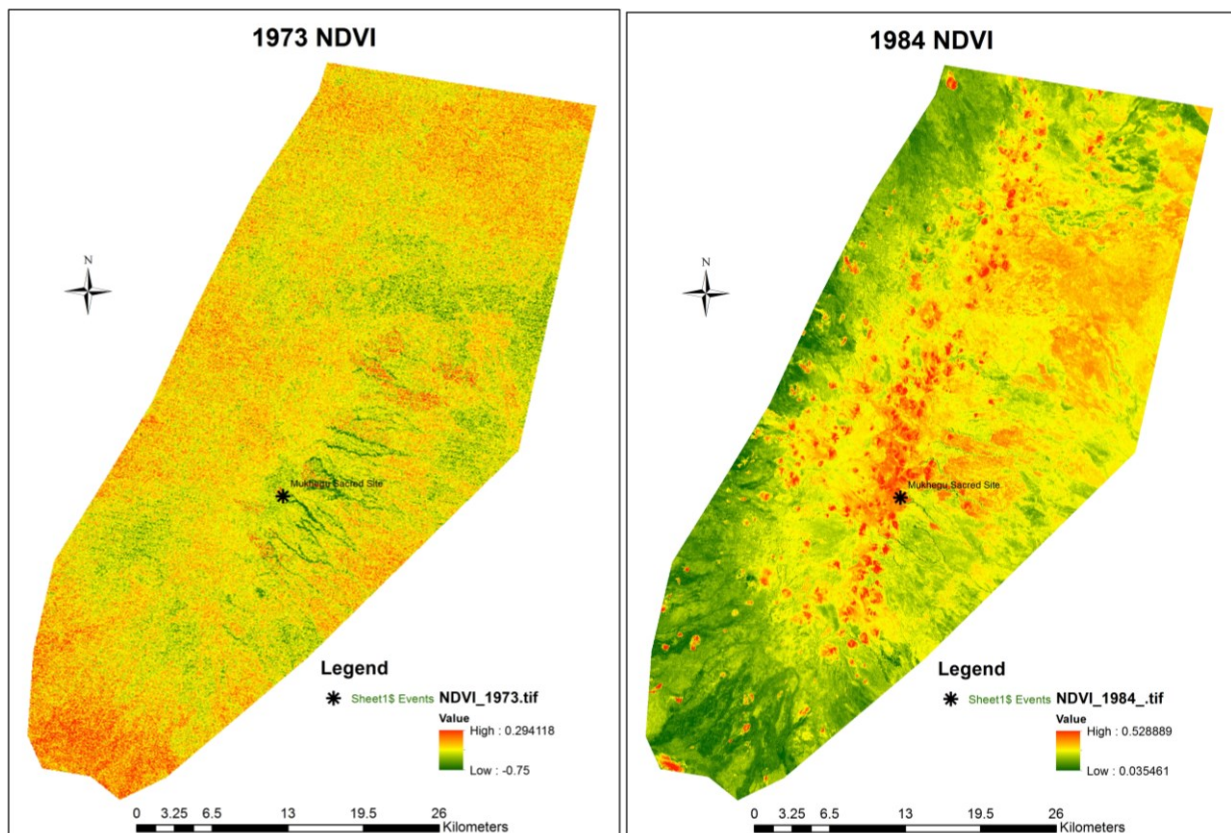


Figure 4.1:NDVI Maps 1973,1984

This study, mainly focused on Mukhegu sacred site to analyze the NDVI of the pixels that lie within it. In the year 1973, NDVI at the sacred grove was high as compared with its

surroundings. In 1984, the NDVI was high as well in the pixels that the sacred natural site fell. NDVI in 1973 amounted to 0.2941 meaning that it picked mostly from the shrubs. The same case applies in 1984.

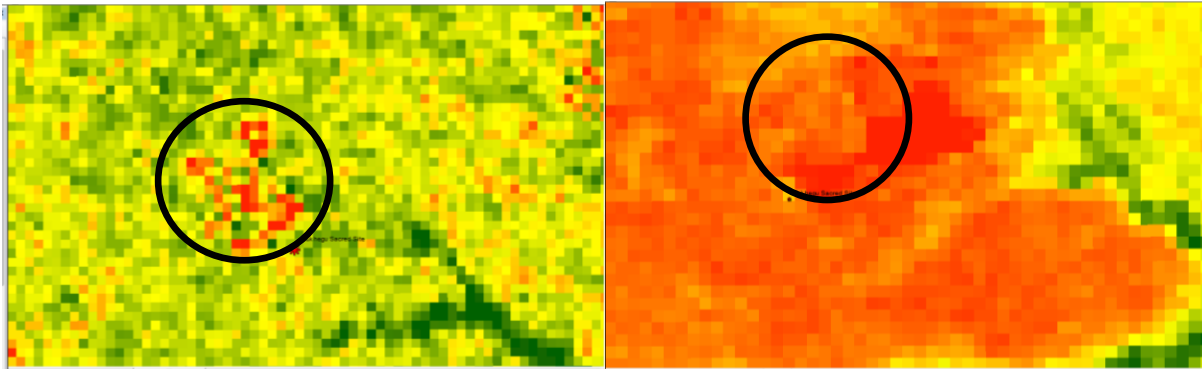


Figure 4.1.1:Zoomed in pixel to indicate high NDVI on the sacred natural site 1973,1984 respectively

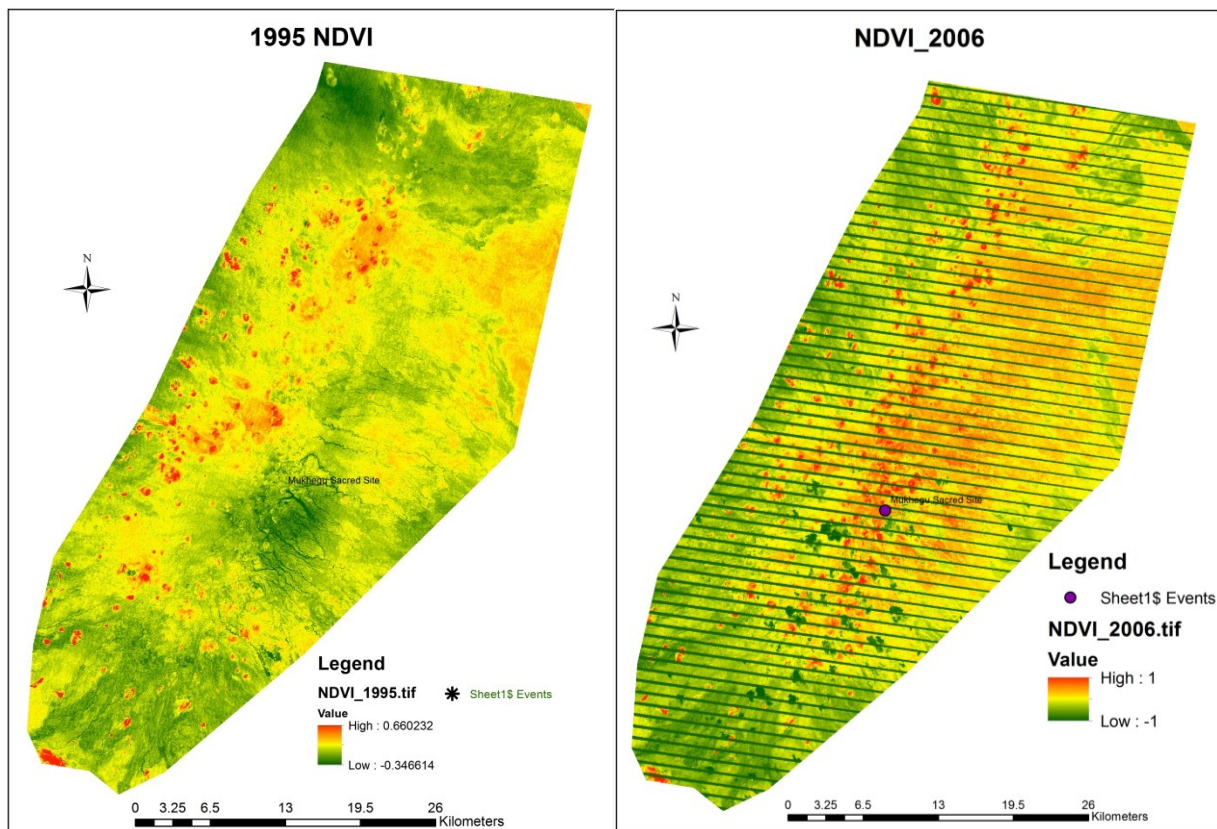


Figure 4.2:NDVI Maps 1995,2006

In 1995, high NDVI was concentrated on certain spots on the image. High values were recorded at 0.660232 while low values were read at -0.346614. In 1995, a closer look at the pixels where the sacred natural site occurred indicated higher NDVI than the surrounding areas.

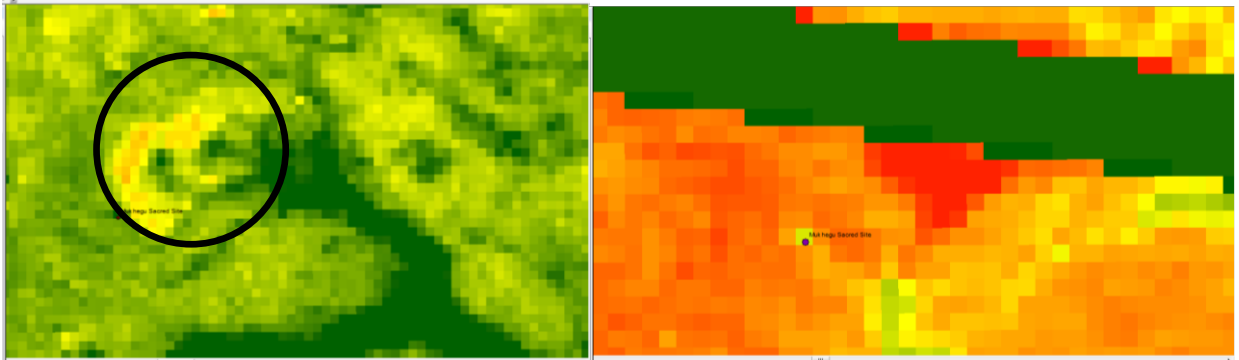


Figure 4.2.1:Zoomed in pixel to indicate high NDVI on the sacred natural site 1995,2006 respectively

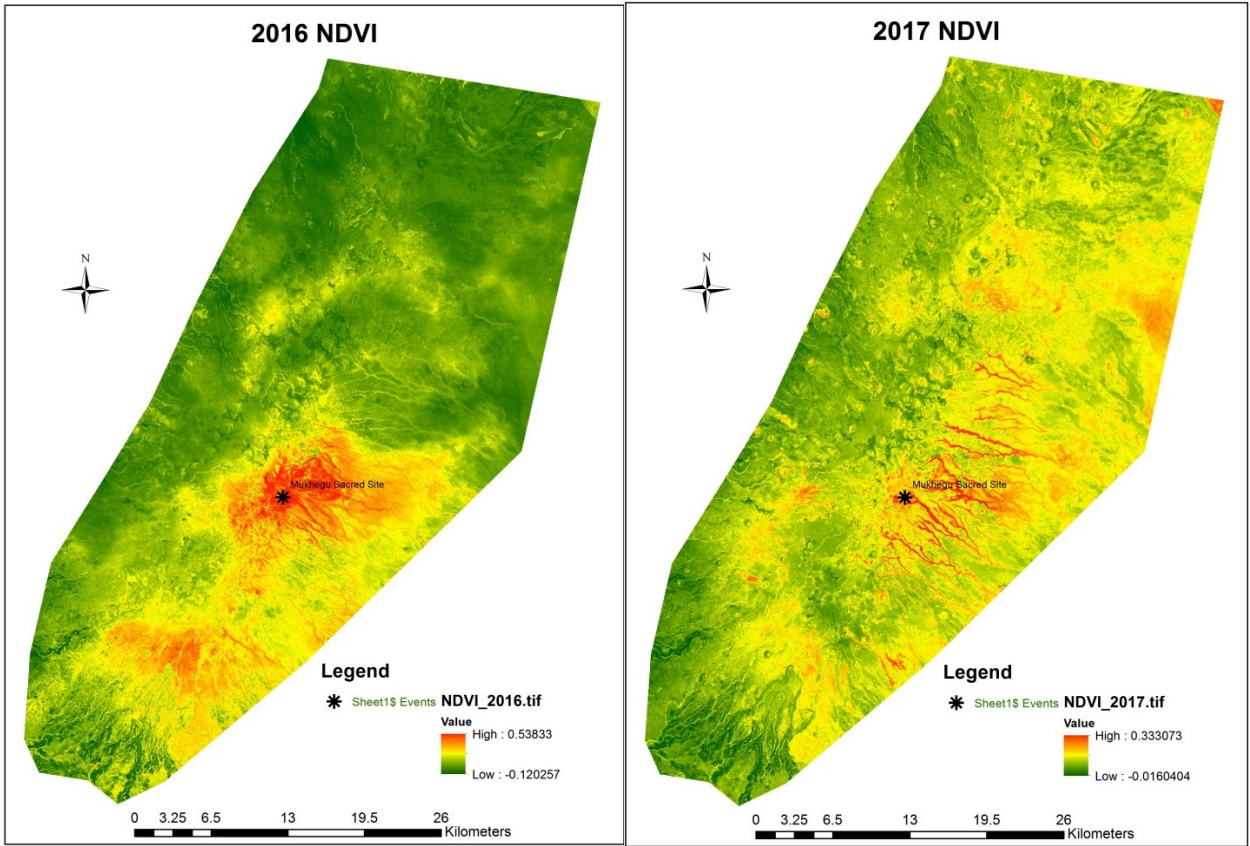


Figure 4.3:NDVI Maps 2016,2017

In 2016,the overall high NDVI amounted to 0.53833 while its low values amounted to -0.120257. NDVI at the pixels where the sacred natural site lie was high.In 2017,the high NDVI values amounted to 0.333073 while the low values read at -0.0160404.The NDVI was high where the sacred natural site lie.

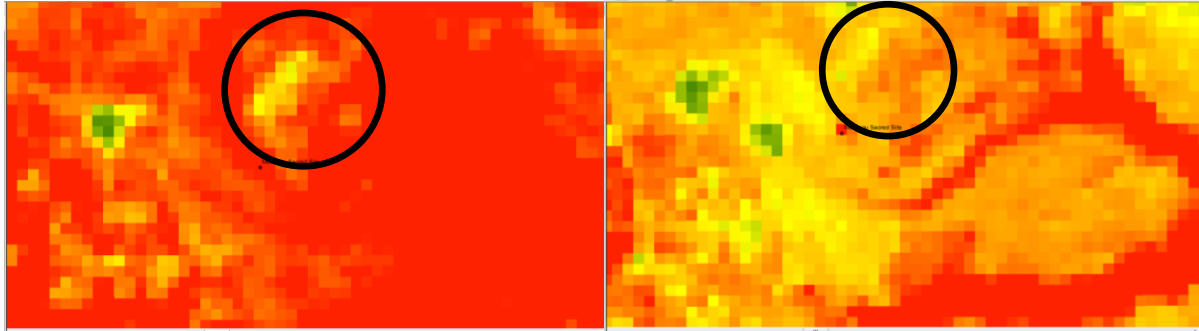


Figure 4.3.1:Zoomed in pixel to indicate high NDVI on the sacred natural site 2016,2017 respectively

4.3 Land Cover of the Sacred Natural Site

Land cover maps were generated are indicated in the figures below. Supervised classification was performed to extract information classes from multiband images.

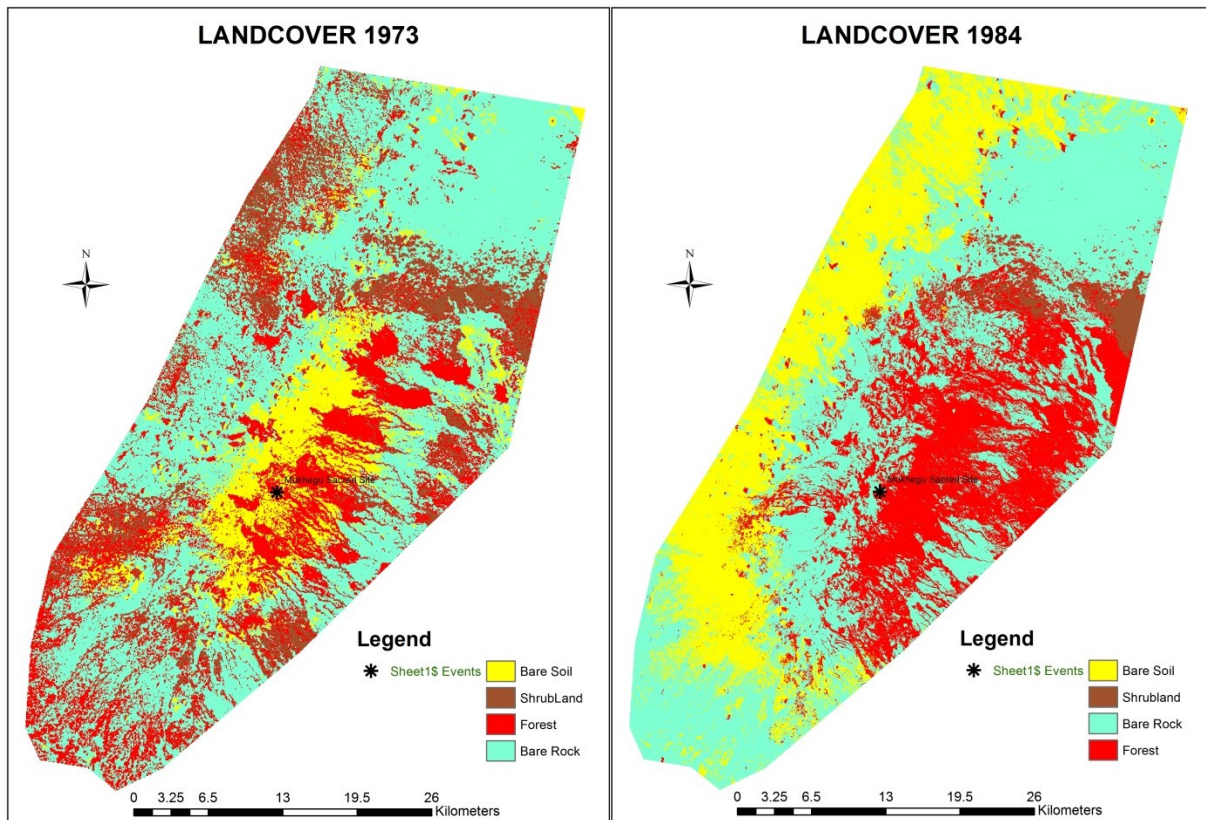


Figure 4.4:Land Cover Maps 1973,1984

In 1973,forest in Hurri Hills was more as compared to 1984. In 1984,the forest areas reduced and more rock was left exposed especially in the lower parts of the image. More soil was detected in

1984 as compared to 1973. The sacred natural site which also a forest remnant remained intact even as the forest cover reduced in other parts on the imagery. In 1984, the sacred grove lost a portion as seen in the imagery.

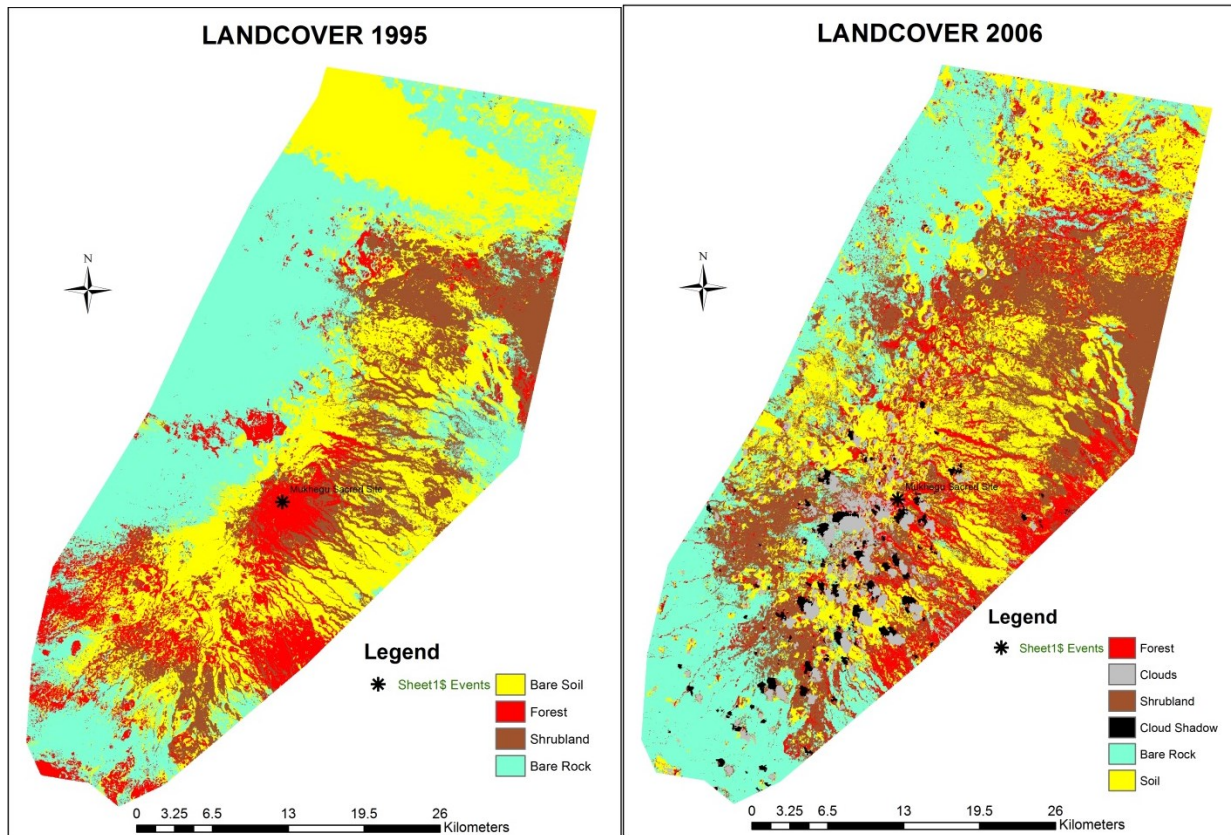


Figure 4.5: Land Cover Maps 1995, 2006

In 1984, there was some forest remnants at the upper top left of the image. There was more forest than 1995 especially on the areas that were covered by shrub land in 1995. In the lower parts of the 1984 image, bare rock was left exposed while in the 1995 image, the forest cover regenerated even in the sacred natural site portion. Shrubland increased in 1995. At the sacred natural site the forest portion that had been depleted regenerated and joined the portion that had not been depleted. In 2006, the previous portion that had been observed was noted again. The part that had regenerated disappeared.

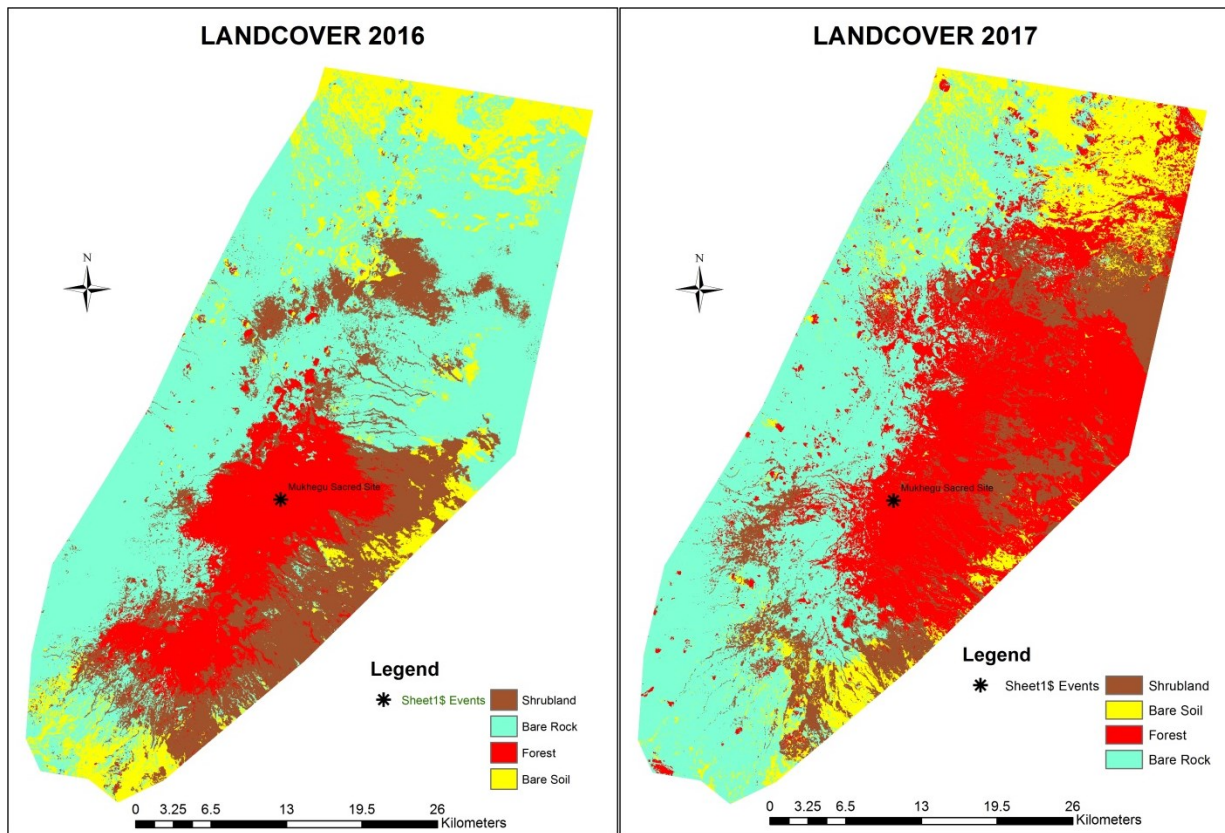


Figure 4.6: Land Cover Maps 2016, 2017

In year 2016, the upper parts of the image lost forest cover and many of the remnants disappeared as well. More bare rock was detected by the Landsat. The soil that could be seen in 2006 was not as detectable as in 2006. In 2016 forest cover was concentrated at the area around the sacred natural site. Shrubland increased in 2016 especially in the lower right areas of the image. The degraded part of the sacred natural site was regenerated as well. Year 2017 was used for validation purposes only hence no comparison was done because for a comparison to be made, a 10 year difference was used.

4.4 Land Cover Change

Land cover change maps were generated using image differencing and were displayed as follows.

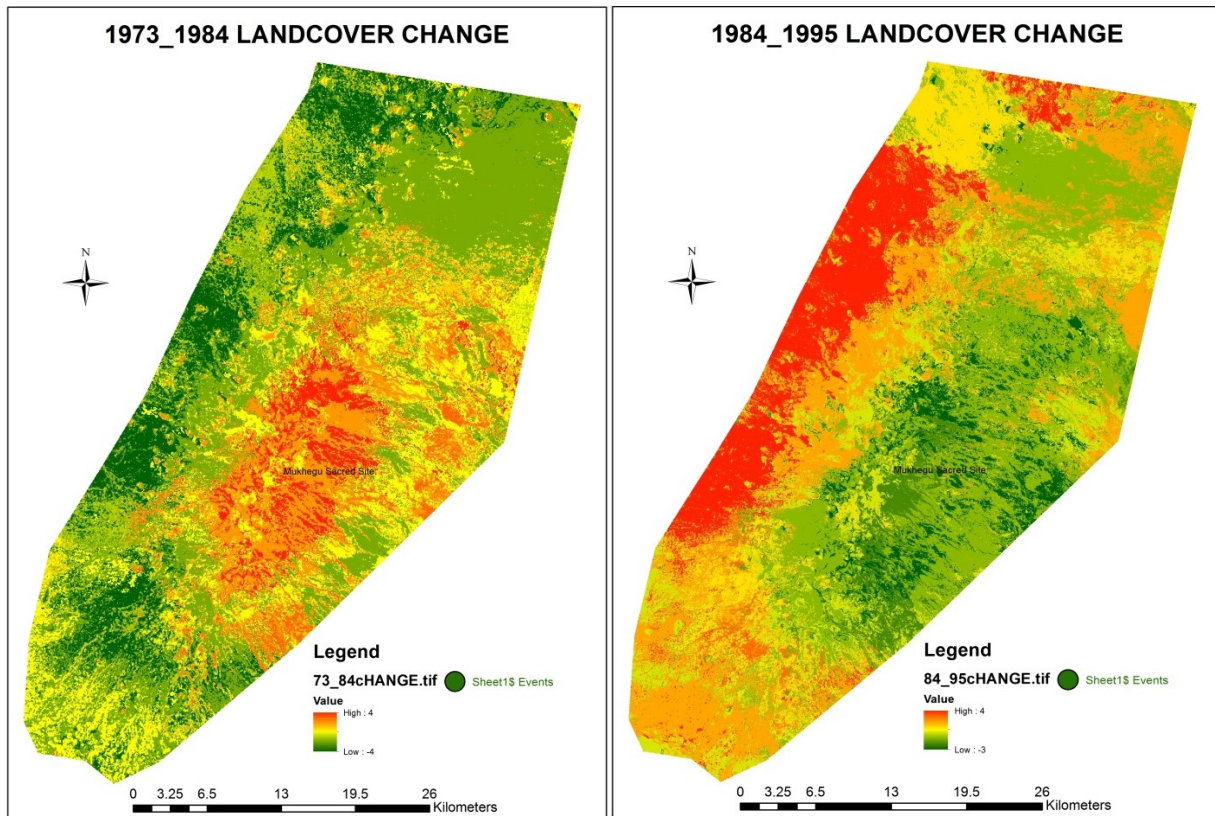


Figure 4.7 : Land cover change Maps 1973_1984:1984_1995

From the Land change map for 1973 and 1984, high change was indicated by the red colour. Near the sacred natural site the change was high as seen on the map. In the landcover change map for the years 1984-1995, high change occurred away from the sacred site.

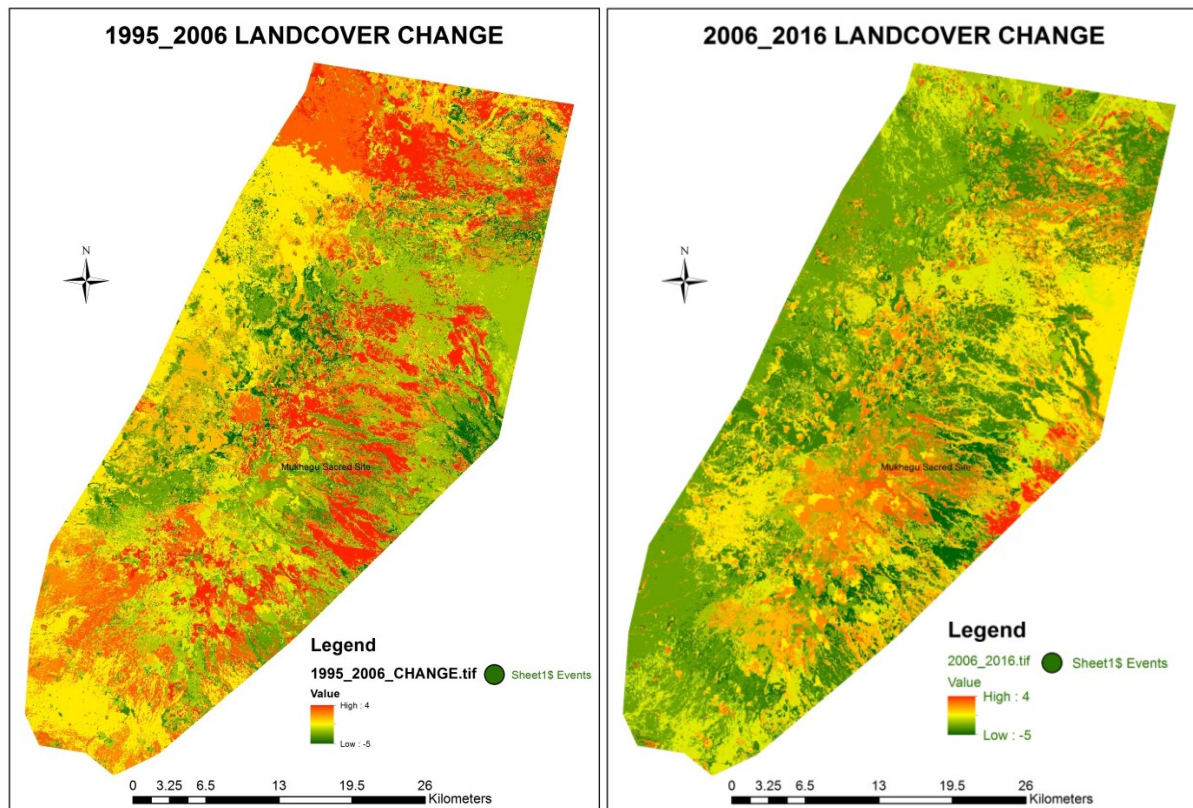


Figure 4.8: Land cover change Maps 1995_2006:2006_2016

In 1995 and 2006 landcover change map, a lot of change happened in the upper left area of the image and very low change around the sacred natural site. In 2006-2016, minimal change happened around the sacred natural site.

4.5 Validation

4.5.1 Accuracy assessment

Accuracy assessment was conducted in ERDAS IMAGINE 2013 and stratified random sampling was used to choose the validation points. Field data was mostly used to verify whether the classification method was accurate. Table 4.1 was thus generated to display the accuracy of the classification.

Table 4.1: Accuracy Assessment Error Matrix

Class	Users Accuracy (Error of commission)	Producers Accuracy (Error of omission) %
Shrubland	21.42	75.00
Bare Soil	5.08	10.00
Forest	23.46	100.00
Bare Rock	80	71.43

Overall Classification Accuracy = 61.76%

4.5.2 Ground truthing

Observation was done for accuracy assessment especially the land cover classes verification. Face to face interviews were used and questionnaire administration. Google earth image was used to verify. Figure 4.9 showing new agricultural land expanding towards the sacred natural site was taken in the field.



Figure 4.9: The agricultural land near the sacred grove



Figure 4.9.1:Google Earth Imagery showing human settlement and urban centre expanding towards the sacred grove

After interviewing the local community as well as the administrative offices in Hurri Hills, majority of the community members expressed the believe that the sacred grove provided resilience in the dryland ecosystem, The elders felt that the sacred trees have a conservation and cultural significance and the two can never be separated since culture has indigenous knowledge that has always ensured that the sacred grove is conserved. One of the elders actually stated that during drought, the areas around the sacred natural site dry up except the sacred grove.

It was easy to notice that agricultural land expansion is one of the main factors that could contribute to the degradation of Mukhegu Sacred Site. A plot nearby was being tilled in preparation for planting. The farm is expanding towards the site endangering the sacred grove which is among the very few remaining in the Northern Kenya. From a raised ground, one could easily notice that settlements are continually expanding towards the sacred site hence threatening the sacred grove. This was confirmed through the satellite imagery which shows the urban centre and human settlements expanding towards the sacred grove.

4.6 Discussion

The NDVI maps were used in this study to verify if indeed the sacred natural site has remained green all through. The vegetation vigour from 1973 was studied from the NDVI maps and it proved a very effective way to demonstrate resilience of the sacred grove to climate change especially against drought. NDVI at the sacred natural site was noted to be high all through the drought years that were chosen for analysis dating 30 years back. It was also easy to note that despite the surrounding areas having low NDVI, the sacred site location has had high NDVI.

NDVI was also used to monitor the sacred groves shape which has over time changed. In 1973 the shape was a bit expansive but overtime it has reduced suggesting a possibility that the sacred groves had more trees which might have been deforested over time. However, the sacred natural site remains of great significance since the initial forest biodiversity still remains preserved.

Land cover change for the sacred natural site changed over years in all other parts of Hurri Hills either positively or negatively but at the trees at the sacred natural site did not change. That means that even when deforestation took place in the major forest area of Hurri Hills, the trees at the sacred natural site remained untouched. Land cover change happened significantly in other parts of the image. However, at the sacred natural site only negligible change occurred. The database was very significant because as it was noted, the organizations which were to provide bio cultural research information had no established database hence making it difficult for the researcher in this study to obtain most information that the study needed. After ground truthing, it was noted that the sacred natural site is in danger of agricultural land expansion like many other sacred natural sites in different parts of the world.

CHAPTER 5: CONCLUSIONS AND RECCOMENDATIONS

5.1 Conclusions

The objectives that the study set out to achieve were accomplished. It was evident that the sacred natural site contributed positively to resilience of the dry land ecosystem to climate change effects in this case drought. Over time the sacred natural site has remained green as shown by the NDVI maps over all the years analyzed. The vegetation in the pixels where the sacred natural site lies showed vigor which was an indication of resilience to the activities of the community as well as the biodiversity around the sacred natural site. Many sacred natural all over the world are thus important. Sacred natural sites form a primary network of nodes for resilience against climate change effects especially for droughts and famines that are being felt in Kenya as noted by Wild et. al (2010). Rapid loss of sacred groves severely threatens the existence of indigenous communities in Kenyan dry lands as these people rely on them for herbs during droughts, as well as pasture for their animals during the recurrent droughts and famine which are brought about by climate change. The methodology also fulfilled the objective of the study which was to create the database and apply in decision making. After calculating the accuracy of the supervised classification using maximum likelihood the results were 61.76% which is an indication that the classification method was accurate.

It is also clear that Mukhegu sacred natural site is threatened by the need for more agricultural land as the pastoralist settle down for farming as a way to diversify their way of livelihood. Ecosystem services emanate from the sacred natural sites as confirmed by the elders who have always been the custodians of the natural sites. The sacred landscape provides pasture to animals and during drought times animals are allowed to graze in the sacred grove. However, the community members are not allowed to permanently move their animals near the sacred sites. Harvesting of dry twigs is only allowed if a community member is to use the dry twigs in the sacred grove but not to take home. Traditional knowledge systems have thus been responsible for conservation in the dry land ecosystem.

The sacred trees have never been cut down hence they are home to indigenous species that have become threatened in other parts of Hurri Hills. Rare grass species are found in the sacred grove while they have become extinct in the surroundings. Normalized Difference Vegetation Index

was appropriate for this study since it was able to show that all through the NDVI has remained high despite recurrent droughts.

Normalized Difference Vegetation Index proved that due to the sacredness of the sacred natural site, species that have become extinct in the surrounding areas can be found preserved in the sacred grove. NDVI was appropriate for this study which took place in a rangeland as noted by Aralova (2016). Rare grass species that were once found in the ecosystem can only be found in Mukhegu Sacred Grove. Forest cover in Hurri Hills has been lost overtime and the highest change happened between 1973 and 1984 epochs.

5.2 Recommendations

This research recommends that further research be undertaken on other sacred natural sites that are mentioned in this report. The landscapes on which they are found might be undergoing changes which affect the sacred natural sites threatening the cultural and conservation aspect of the Gabbra Community.

More funding should be directed towards this area to ensure that the few remaining sacred sites are conserved and rehabilitated. Indigenous knowledge should be documented especially by the indigenous communities so that generations can use it in conservation. This will ensure the continuity of the traditional conservation efforts.

Policies should also be made that aim to conserve the cultural landscapes since resilience emanates from them and they are at the verge of extinction. Indigenous communities look up to these lanscapes for their survival especially when their ecosystem are hard hit by climate change hazards.

Environmental Impact Assessments where the Indigenous Communities are engaged should always be done before any development is undertaken in landscapes that are of cultural value. This will avert instances whereby developers encroach sacred natural sites without knowledge of their existence.

Public awareness should be thoroughly done on the significance of sacred natural sites in conservation and mitigation of climate change adverse effects. Rehabilitation of the deforested area in Hurri Hills should be initiated and taken seriously since it is a water tower.

The sacred sites should be fenced to protect the few remaining biodiversity species. Ecological resilience is provided by the sacred sites and the ecosystem services emanate from them. Policies

that protect the sacred natural sites in Kenya are inadequate and there is need to ensure that such policies are made and implemented.

It is important to ensure that the conservation role that the sacred natural sites play is not taken for granted for it leads to a malfunction in the conservation network system that is formed by several sacred natural sites.

Finally, landscapes and sacred natural sites cannot be separated and this should be learnt by the organizations and government offices that are in charge of the environment. If a development project is to take place in a cultural landscape, it should be approached with caution since it will have an impact on the cultural systems that are found in that landscape.

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Appendix 1: Questionnaire

Knowledge, Practices and Attitude Study for Contribution of Sacred Natural Sites to the Resilience of Climate Change Effects in Dryland Ecosystem, Case Study Hurri Hills for Masters in Geographic Information System, University of Nairobi.

Name:

Gender Male Female

Coordinates

1. Which are the sacred natural sites located in Huri Hills?
2. What is their extent?
3. In what form are they? Single trees, rocks, wetlands, Forests, Forest Patches
4. What do you know about the sacred natural sites i.e. what is their use to the community
5. Do you understand Climate Change?
6. What would be different if it was not for them especially when intense climate change effects are being felt e.g diseases, drought or even floods?
7. What are the indicators of climate change in regards to the sacred natural sites?

Attitude

20 What is your attitude towards the sacred natural site?

21. What is the attitude of the community towards the same?

22. What is the attitude of the visitors towards the same?

23. Practices

24. Are there specific practices/festivals that take place near or within the sacred natural sites?

25. This being a drought year, are there any decisions/practices that have been made at the sacred natural sites?

26. Have the practices impacted on the community's resilience toward climate change?

Thanks!