ENVIRONMENTAL FACTORS INFLUENCING ECOTONAL CHANGES IN AN INDIGENOUS FOREST IN THE KEISKAMMAHOEK FOREST ESTATE, EASTERN CAPE, SOUTH AFRICA

BY

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Declaration

I, Luthando Kiva, declare that the dissertation hereby submitted for the degree of Masters of Science in Geography at the University of Fort Hare is my work and has not been previously submitted to another university for any other degree.

Signature:...

Date:...

Place: University of Fort Hare, East London Campus

Preface

This document comprises 6 chapters. Chapter 1 provides an introduction to the topic and further outlines the overall aim and objectives of the study. Chapter 2 consists of a literature review. Chapter 3 of this document explains the methods used in the collection of vegetation and, physiographic data from various research sites in the study area. This chapter also outlines the analysis and interpretation of aerial photographic data which was used to assess the scale of forest edge movement. Chapter 4 reports on the results generated by the methodology employed as described in Chapter 3. Chapter 5 provides contextualisation and interpretation of the results. Chapter 6 gives the conclusions and recommendations based on the findings of the study.

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This work is dedicated to my lovely wife Babalwa and my two sons Aphendule and Simazi Kiva, they have been patient and supportive in the period of this research.

Abstract

This study investigates environmental factors influencing ecotonal changes in the Dontsa Forest Management Unit (FMU) of the Keiskammahoek Estate Forest which is located in the Amatole Mountains of the Eastern Cape in the Republic of South Africa. The patterns of forest edge movement were analysed to show trends of forest edge movement from 1975 to 1985, 1975 to 1992, 1975 to 2002, 1975 to 2014, 1985 to 1992, 1985 to 2002, 1985 to 2014, 1992 to 2002, 1992 to 2014 and 2002 to 2014 by digitizing and assessing the scale of forest edge movement using georeferenced aerial photographs. Belt transects were established in six sites that were selected on the basis of physiographic elements for determination of the driving forces of forest ecotonal changes. The results of the study show that the forest edge moved positive towards the grassland biome while in other sites there was contraction of the forest edge from 1975 to 2014. The findings of the study show that some forest patches moved with few individual pioneer species towards the grassland while indigenous species dominated in the ecotone area of the forest in other research sites. *D whyteana*, *A latifolius, R melanophloes*, *A facultus, R prenoides, C aurea*, *C bispinosa*, *C inerme*, *and S martina* are the plant species with high density in the forest ecotone while *A latifolius, R prenoides, R melanophloes* were highly distributed along the grassland area. The results also show that harvesting of *Pinus patula* and illegal harvesting of understory species are major factors that result in ecotonal changes of Dontsa FMU. The research sites adjacent to residential areas have experienced reduction of ecotone area as compared to the research sites in high altitude areas of the Amathole Mountains where there is less disturbance. The eastern facing aspect of the forest exhibited a high density of plants in the forest ecotone as compared to the west facing slope.

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List of acronyms

DAFF Department of Agriculture, Forestry and Fisheries
FMU Forest Management Unit
GPS Global Positioning System
GIS Geographic Information System
SP Sampling
UGS Urban Green Space
WTH Whole Tree Harvest

CHAPTER 1: INTRODUCTION

Ecotones are defined as transition zones between two adjacent ecological systems, and they are sensitive to both natural and human-related disturbances (Pogue and Schnell, 2001). It is a critical area of transition in terrestrial ecosystems and is susceptible to global climatic changes (Xudong and Yuxig, 1998). The forest ecotone has more biological diversity and is more vulnerable to global climatic changes and has edge effects (Zhu *et al.*, 2011). Forest–grassland ecotone change has been observed in various parts of the world and is attracting more attention due to its implications for global carbon sequestration and land surface–atmosphere interactions (Sankey *et al*., 2006). Ecotones that divide forests and meadows are very sensitive to variation in environmental factors, and they provide useful locations to evaluate the impact of climate and land use change (Norman and Taylor, 2005).

Ecotone vegetation may be susceptible to various effects such as fire and human disturbances due to the fact that many species are at the limits of their natural ranges (Gosz, 1992; Risser, 1995). However, there are many other factors that influence ecotone change such as fire, slope angle, altitude and anthropogenic activities. This study aims to investigate driving factors of forest edge movement in the Dontsa Forest Management Unit (FMU); an indigenous forest of Keiskammahoek Estate Forest in the Eastern Cape, South Africa. Six research sites showing different physiographic and plant characteristics have been identified for the purpose of the study.

1.1 Statement of research problem

It has been observed by the Forestry Scientist of DAFF that indigenous forests have the potential to change in spatial extent due to different environmental factors (Kameni, pers. com). Forest ecotones serve as a protection structure of the forest and indicator of forest cover change, positive movement of the forest edge indicates forest health while the negative movement of the forest edge is an indication of forest loss (Puyravaud *et al.,* 1994) which requires intervention for the protection of the forest ecosystem. The negative movement of the forest edge results in the interior of the forest being exposed to environmental factors that are highly destructive to the forest ecosystem. It is also important to identify environmental factors that contribute towards the movement of the forest edge. The identification of environmental factors that result in forest edge movement will contribute to the development of a forest management plan and the appropriate response method in dealing with such factors. Although the process of forest edge movement has been reported in the literature (e.g Norman and Taylor, 2005; Vogelmann et al., 2012; Carmona, 2012; Czerwinski et al., 2014), there is still paucity in literature on scientific assessment of natural forest edge movement, particularly in the context of South African environment.

1.2 Rationale of the research

This research provides insight into the process of forest edge movement. The investigation contributes to the identification of factors that drive changes in forest ecotones. The outcome of this study is expected to provide recommendations that will assist forest managers and environmentalists to establish sustainable forest management approaches. Thus, the study supports the principles and objectives of sustainable management of natural resources prescribed in various South African Governmental documents and international treaties (e.g. White paper on sustainable forest management and the National Environmental Management Act, 1998).

1.3 Research Aim

The main aim of the study is to investigate the driving factors of forest edge movement in the Dontsa Forest Management Unit (FMU); an indigenous forest located in the Keiskammahoek Estate Forest in the Eastern Cape of South Africa.

1.3.1 Specific Objectives

a) To assess the scale of forest edge movement.
b) To investigate the relationship between plant species density, plant species richness and forest edge movement.
c) To study how the slope altitude, angle and orientation affect forest edge movement.
d) To investigate how cutting of indigenous trees and harvesting of *Pinus patula* plantation affect forest edge movement.

1.3.2 Research questions

a) What is the scale of forest edge movement?
b) Is there a relationship between plant species density, plant species richness and forest edge movement?
c) How does slope altitude, angle, orientation affect forest edge movement?

d) How does cutting of indigenous trees and harvesting of *Pinus patula* plantation affect forest edge movement?

1.4 Description of the study area

Dontsa FMU (Fig. 1) covers 5 216ha of forest land in the area located on the Amatole mountain range (DAFF, 2008). The FMU is located on the North East Mountains of Kesikammahoek. It consists of large and small fragments of Afromontane forest patches interspersed between exotic commercial timber plantation and communal grassland along the southern slopes of the Amatola Mountain Range. Dontsa Indigenous forest has been classified according to DAFF, (2008) forest management plan. The FMU comprises dry high forest as indicated by the presence of *Diospyros whyteana* and *Olea capensi*. Some forest patches are classified as dry scrub because of the presence of *Cheatachma aristata* and *Hyperacanth amoenus*. The FMU is classified as medium moist high forest due to the dominance of *Podocarpus latifolius* and *Rapania melanophloeos* on the eastern part of forest.

The area experiences periodic snow falls during the year in the high lying areas and frost is known to be prevalent up to December (SAWS, 2012). It also experiences hot berg winds which is often followed by icy cold, snow and frost which occurs about ten nights a year from June through to August (SAWS, 2012). Annual rainfall varies from place to place, closely linked to altitude, and ranges between 850 mm to over 1 600 mm, peaking in March and November (SAWS, 2012). Sections of the forest are high in the mist belt area (DAFF, 2008).

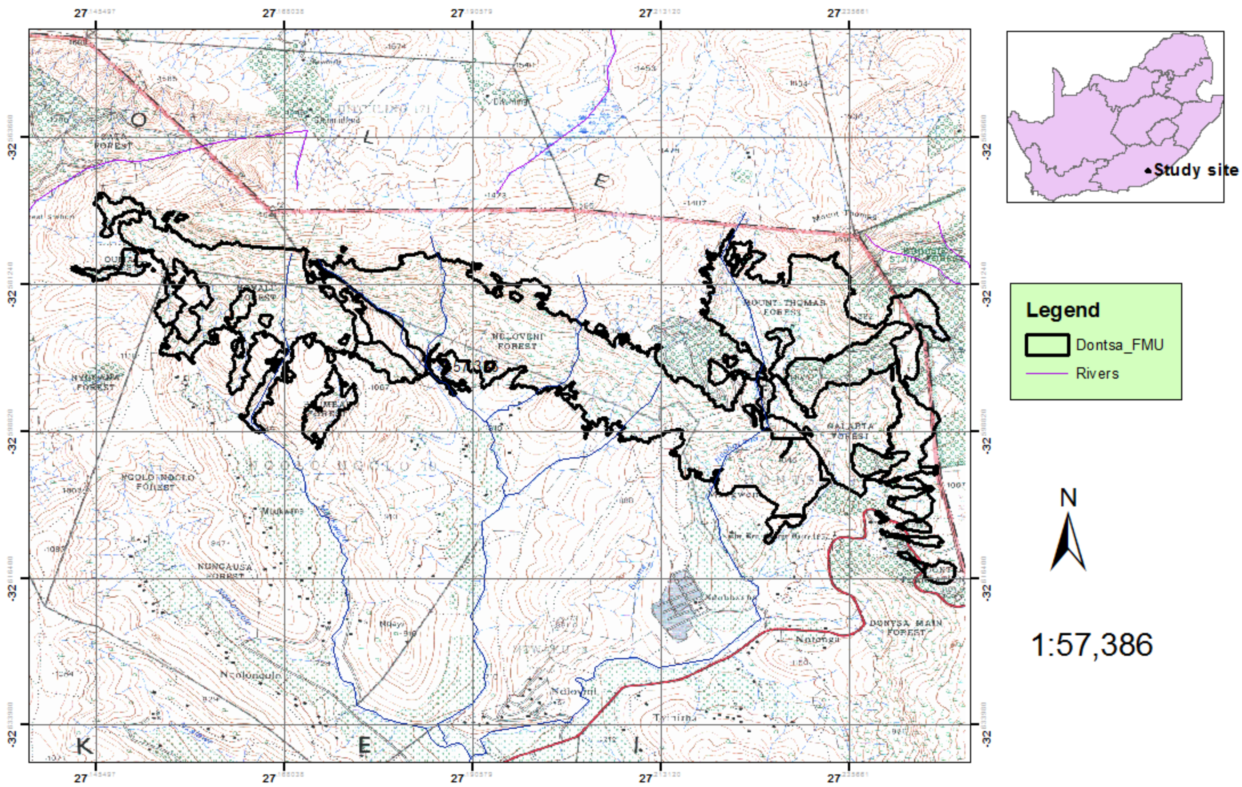

Figure 1. Map showing Dontsa FMU

1.4.1 Description of research sampling sites

The study of forest edge movement was conducted in six research sampling sites located in different zones of the Dontsa forest management unit (Figure. 2). Below is the description of the research sampling site:

Table 1. Description of research sampling sites

Research site	Description
1	• Research site 1 is located at an altitude of 1128m with slope inclination of 45° and slope aspect facing the South East (SE) direction. This site is closer to the settlement area

	called Dontsa and it is vulnerable to grazing and browsing pressure. Cutting of trees was observed along the forest edge in this site.
2	• Research site 2 is located on the eastern part of the forest. Sampling site 2 is located at an altitude of 1167m with a degree of slope of 15° and slope facing South West (SW) direction. It is characterized by a wetland in the grassland with abundance of seedlings growing in the buffer zone of the forest.
3	• Research site 3 is located at an altitude of 1197m with 0.5° degree of slope and SE aspect. The site exhibit high vegetation cover in the buffer zone which include shade tolerant and pioneer species growing in high density as forest ecotone.
4	• Research site 4 is found at an altitude of 1128m in the catchment area of the forest with a degree of slope which is 45° and SW aspect. The site is adjacent to commercial forest plantation site.
5	• Research site 5 is characterized by presence of bush clamps in the buffer zone of the forest site. It is in the catchment of the forest at 1197 m altitude with a degree of slope of 25° and SW and SE aspect.

6	• Research site 6 has forest patches that occur in the SW and SE aspect with a transition zone extending towards the grassland. The site is located at 927 altitude with slope inclination of 40°.

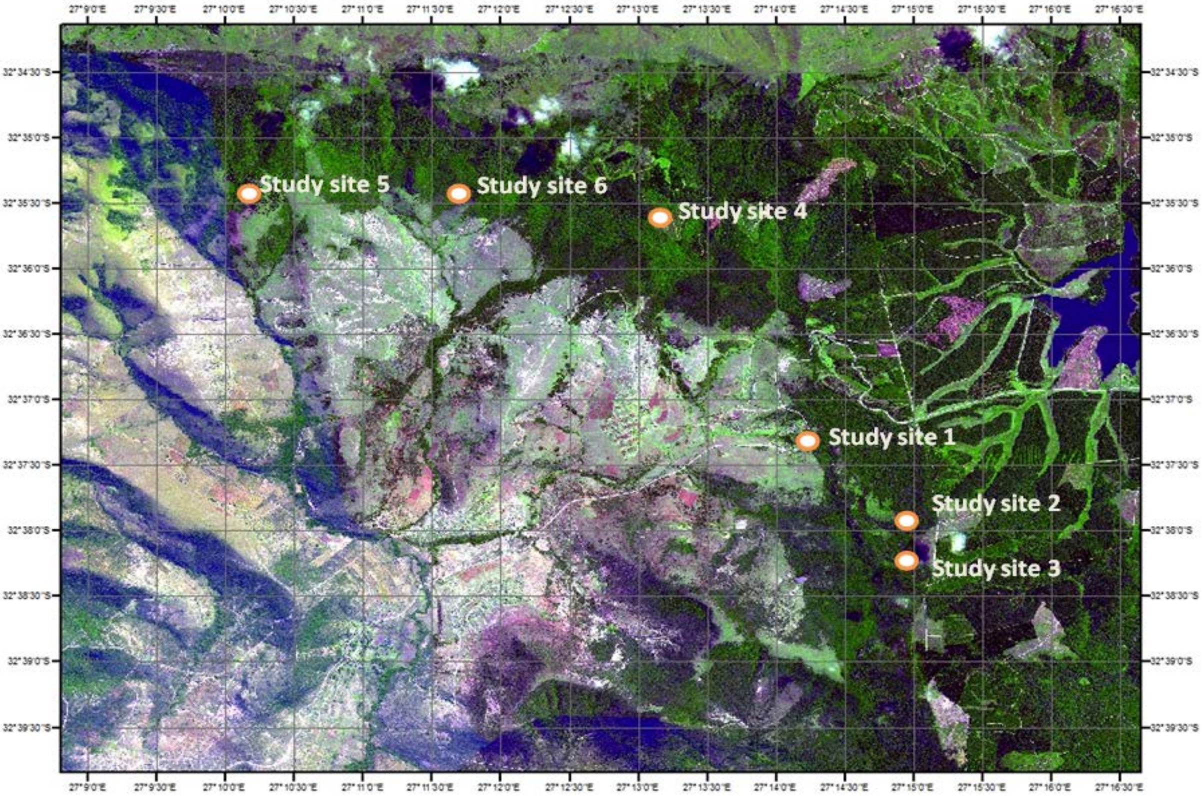

Figure 2. Location of research sampling sites in Dontsa FMU

1.5 Scope of study

This research focuses primarily on forest edge movement in the Dontsa Forest Management Unit. It seeks to understand the underlying causes of forest edge movement. Possible drivers of forest edge movement that are considered in this study are limited to selected plant characteristics, topographic factors and anthropogenic activities.

CHAPTER 2: LITERATURE REVIEW

This chapter provides overview of relevant research work that has been done by other researchers. The chapter also highlights different methods and models that were employed in the previous studies.

2.1 History of indigenous forests in South Africa

The widespread perception among South Africans is that human influences during the past 300 – 400 years have been responsible for extreme reductions in natural forest. Before the first settlement of the Dutch East India Company at the Cape, almost all of the coastal plateaux and sea-facing mountain slopes were clothed in natural forest, and from the 19th century onwards. The current situation is the result of extensive destruction by humans, either directly or indirectly (Stehle, 1992). Literature reveals that indigenous forests were heavily exploited in the colonial era and immediate post-colonial era, and that in certain areas such as Qudeni and Nkonyana forests in KwaZulu Natal, this exploitation had a serious impact (McCracken, 1986). King (1938) estimated that in the 167 years from 1772-1938, 700 000 m^3 of timber was extracted, 50% was *Afrocarpus spp* (previously known as

Podocarpus spp)., 17% *Ocotea bullata* and the remaining 33% comprised various other woods.

2.2 Human impact in the past

Sontag (1938) reported over-utilization of forest resources, highlighting that the yellowwood species (Common and Real) have always constituted the bulk of the yield and have had a ready market. There are plant species which were sold for commercial purpose and they include Black iron wood, Assegai, White ironwood, Sneezewood, Red Currant, White pear, Camdeboo, Stinkwood, Wild Chestnut, Knobwood, Hard pear, Saffraan, Red Els, Red Pear and Wild Lemon (Sontag, 1938).

In the nineteenth century, before effective controls were introduced, forests were filled with dry and rotting wood debris left behind by wood cutters (Lawes *et al*., 2004). Grass fires, set either deliberately by natural causes, were considered to be a threat to forests (Lawes *et al.*, 2004).

2.3 Economic impact on the indigenous forests

The indigenous trees from various indigenous forests were harvested mainly as a timber for building material (Sim, 1906). The species that were sold include *Ocotea bullata* (with 3 230 average number of trees sold per annum), *Afrocarpus facaltus* (with 4 977 average number of trees sold per annum), *Podocarpus latifolia* (with 852 average number of trees sold per annum), *Curtisia dentata* (with 3 452 average number of trees sold per annum), *Xymolos monospora* sold 53 tress from 1895-1900, *Ekebegia capensis* sold 12 from 1895-1900, *Celtis africana* sold 115 from

1895-1900, *Caledendron capense* sold 215 from 1985-1900 and *Kiggelaria africana* selling 60 trees from 1895-1900 (Sim, 1906). A number of forest patches of Amathole were degraded in the past mainly because of harvesting of timber and it has been reported that the sawmills were created for the purpose of timber processing (Sim, 1906).

2.4 Establishment and management of indigenous forests in the past

In 1859 forests that had suffered during the early wars were protected under the Herbage and Forest Act of 1859 but burning and wasteful felling of timber continued until 1877, with the forest at Katberg and along the Amathole Mountains of Eastern Cape heavily affected (DAFF, 1989). By 1885, the Department of Forestry assumed control of the forests and some semblance of order was instituted. The colonial botanist, Robert Brown took the conservation of the forests up as a goal and in 1863 produced a memoir on the subject (Comins, 1962). After sometime, Captain Baron de Fin was appointed Conservator of Forests with headquarters at Keiskammahoek (Daff, 1989). In 1885 a Forestry Commission was appointed by the Government to demarcate the forests and to settle disputes affecting them, and three years later the Forest Act No. 28 of 1888 was passed and regulations were gradually brought into force which made provision for better control of the forests (Comins, 1962).

Currently, forests in South Africa are managed by the Department of Agriculture, Forestry and Fisheries under National Forestry Act no 89 of 1998. The objectives of the Act are to: promote the sustainable management and development of forests for the benefit of all; create the conditions necessary to restructure forestry in State forests; provide special measures for the protection of certain forests and trees; promote the sustainable use of forests for environmental, economic, educational, recreational, cultural, health and spiritual purposes; promote community forestry; promote greater participation in all aspects of forestry and the forest products industry by persons disadvantaged by unfair discrimination (National Forestry Act of 1998).

2.5 Factors affecting forest ecotone

This section describe different factors that contribute significantly to the transformation of the forest ecotone. It highlights environmental issues such as land use activities, livestock grazing and browsing and tree harvesting as anthropogenic activities that result in forest degradation and in the reduction of forest area, structural complexity, species richness and forest regeneration.

2.5.1 Anthropogenic activities

2.5.1.1 Land use

Forest destruction and fragmentation are amongst the most complex ecological issues facing developing countries (Cayuela *et al.*, 2006). At the landscape level, results of fragmentation consist of habitat loss for some plant and animal species, habitat creation for others, reduced connectivity of the remaining vegetation, decreased patch size, increased distance between patches, and an increase in edge at the expense of interior habitat (Cayuela *et al.*, 2006).

Deforestation is a main cause of species extinctions (Foley *et al*., 2009), high carbon levels and climate change at local and international scale (Pielke *et al*., 2002). Tropical dry forests are one of the most threatened ecosystems worldwide (Hoekstra *et al*., 2005). Major dry forest areas have been cleared for agricultural development and show a highly fragmented landscape with a variety of crops, disturbed forests and remnants forests (Gasparri and Grau, 2009).

2.5.1.2 Livestock grazing and browsing

Growth and development of tree seedlings to attaining sub canopy or canopy status is prevented by grazing, but unlike seedlings, saplings may not be killed immediately when browsed in the forest ecotone (Hester *et al*., 2000). The development of forested vegetation can be disturbed by intense browsing and grazing by mammals (Luoga *et al*., 2002), and recovery and restoration of woody species in the forest is improved by zero-grazing (Zida *et al*., 2007). Negative effects of grazing on forested species, include: slow growth rate of most woody species. When grazing is repeated the plant in the seedling stage are most vulnerable to grazing; as extreme grazing causes shoot loss, damage of plant tissue, and biomass loss for non-timber species (Sankey *et al*., 2006).

2.5.1.3 Tree harvesting

A great number of research projects conducted in the boreal region have demonstrated that whole tree harvest (WTH) can result in growth losses both after thinning (Helmisaari *et al*., 2011) and no, or slightly negative, effects on seedling growth after clear cutting WTH seems to affect soil exchangeable cations, rather than than soil nitrogen or phosphorus (Tamminen *et al*., 2012). The majority of tropical forests, including those in protected areas, are affected by anthropogenic activities (MacKenzie *et al*., 2012; Olupot *et al*., 2009). The harvesting of forest products for livelihoods can affect forest regeneration, structure and diversity (Olupot, 2009).

2.6 Topography

Results by Green and Hawkins, (2005) suggest that environmental restrictions on sub-boreal mixed wood stands vary between north- and south-facing slope aspects, resulting in distinctive competitive relations between plant species. The most efficient height growth of trees should occur at a right angle to the ground, resulting in stems that incline in a downhill direction on slopes (Lang *et al.*, 2010). According to Lang *et al.*, (2010) in a uphill direction, the trees can reach the higher canopy more easily because the typical canopy height is lowest on this side. Thus, on sloping ground the interplay of both abiotic and biotic factors may result in stem inclination together with crown asymmetry (Lang *et al.*, 2010).

2.7 Overview of previous research methods

This section gives an overview of research methods that were used by various researchers in the field of forestry. It also highlights the results that were produced in line with the method used.

2.7.1 Use of remotely sensed data and remote sensing methods for the study of forest cover changes

Brink *et al.,* (2014) assessed and quantified the land cover change in the region of East Africa by applying a logical sampling of medium resolution Landsat and DMC Deimos imagery. There were 445 samples of 20 km x 20km covering about 3% of the study area taken around each 1 degree latitude and longitude intersects that were processed and analyzed (Brink *et al.,* 2014). Land cover change statistical estimates were produced by means of an automatic object-based classification in seven broad classes for the years 1990–2000 and 2000–2010. Results of the study highlight the geographical distribution of land cover dynamics and show a 28% expansion in agriculture area over the analyzed 20-year time frame (Brink *et al.,* 2014). The yearly agriculture area increase rate was around 1.4% for both assessed decades, however an increase in yearly deforestation rate from 0.2% in the first period to 0.4% in the second period was observed (Brink *et al.,* 2014).

Changes to the boundaries of 50 monsoon rainforest patches were assessed using temporal sequences of digitised aerial photography, with a view to understanding the relative importance of the cause of change (Banfai and Bowman, 2006). Boundaries were compared for each of the years 1964, 1984, 1991 and 2004. Vegetation types were manually classified for each year with a 20 by 20 m point lattice, based on the distance between tree crowns. Transition matrices, size-class distributions and fragmentation indices were calculated. Field samples of a subset of 30 rainforest patches supported the precision of the GIS-based mapping of rainforest boundaries. Rainforest patches increased in size between 1964 and 2004 by an average of 28.8%, with an average area increase of 4.0 ha. According to Banfai and Bowman, (2006) the expansion was likely to have been primarily driven by increases in variables such as rainfall and atmospheric Carbon dioxide, but was also strongly mediated by fire regime (Banfai and Bowman, 2006).

Using remote-sensing data, statistical sampling, and change-detection methods, Drummond and Loveland (2010) revealed how land conversion differs spatially and temporally across the East of United States from 1973–2000, and how those changes affect regional land-change dynamics. The analysis showed that agricultural land use has continued to decline, and that this enables forest recovery; however, an important land-cover transition had occurred, from a mode of regional forest-cover gain to one of forest-cover loss caused by timber cutting activities and other land-use projects (Drummond and Loveland, 2010).

2.7.2 Methods used to determine plant species density and plant species richness

A study of density, diversity and richness of woody plants in urban green spaces (UGS) was conducted in Chennai metropolitan city where a tree diversity inventory was carried out (Muthulingam and Thangavel, 2012). A total of one hundred 10 m x10 m (total 1 ha) plots were laid to reveal tree diversity and richness of UGSs. Trees with ≥10 cm girths at breast height (gbh) were recorded. There were 45 species in 42 genera and 21 families that were recorded (Muthulingam and Thangavel, 2012). *Caesalpiniaceae* and *Fabaceae* each with six species dominated the study area followed by Arecaceae (3). Density and stand basal area of the study were 500 stems ha−1 and 64.16 m2, respectively. Most of the inventoried trees were native (31 species) and deciduous (28 species). The study area was dominated by Fabaceae and Caesalpiniaceae in terms of stand basal area and density. The Shannon diversity index and evenness of study area were 2.79 and 0.73, respectively (Muthulingam, and Thangavel, 2012). The most important species and families based on species important value index (IVI) and family important value index were *Albizia saman, Polyalthia longifolia and Azadirachta indica*; Fabaceae, Caesalpiniaceae and Annonaceae respectively. Muthulingam and Thangavel, (2012) establish that Chennai's urban forest is comparatively greater in stand basal area and species richness than many urban forests of the world

Forests cover a bigger area of the earth's surface and are frequently logged (Clark and Covey, 2012). Ecological theory and the findings of extensive silvicultural studies emphasise the role of disturbance in maintaining species richness in forest ecosystems; however, logging and other human initiated disturbance is often credited with the degradation of forest ecosystems all over the world (Clark and Covey, 2012). The results of a meta-analysis of 19 published studies investigating 25 distinct paired human-disturbed and primary forests in the tropical and temperate biomes were presented by Clark and Covey, (2012). Even though logging levels may rise the richness of early successional tree species, it can reduce the richness of late successional trees (Clark and Covey, 2012). According to Clark and Covey, (2012) this happens both through the changing biotic and abiotic processes regulating resource availability and through size-class and species based selection biases normal in logging. Logging also results in most important forests being characterised by open gaps (Clark and Covey, 2012).

2.7.3 Methods used in the assessment of anthropogenic factors

Wilson *et al.,* (2010) conducted a study about the response of a small mammal community associated with Afromontane forests at the Mariepskop State Forest, Mpumalanga, South Africa to edge effects at three different habitat transitions: natural forest to grassland (natural edge, structurally different vegetation types), natural forest to mature plantation (human altered edge, structurally similar vegetation types) and natural forest to harvested plantation (human altered edge, structurally different vegetation types). Wilson *et al.,* (2010) predicted that edge effects should be less severe at natural ecotones and at similarly structured contiguous vegetation types than human-altered ecotones and differently structured contiguous vegetation types, respectively. Wilson *et al.,* (2010) found that forest species seemed to avoid all habitat edges in the study area. Unexpectedly, natural edges supported a less diverse small mammal community than human-altered forest edges (Wilson *et al.,* 2010). However, edge effects were observed deeper into native forests surrounded by mature alien plantations than into native forests surrounded by native grasslands. The net effect of mature plantations was therefore to reduce the functional size of the natural forest by creating a larger edge (Wilson *et al.,* 2010).

Heilmayr, (2014) assessed the effects of plantation expansion on the area of natural forests using a simple partial equilibrium model and a global panel dataset of forest statistics. The analysis showed that plantation expansion has resulted in a reduction of natural forests conserved for forest product extraction. The model and practical evidence emphasized, however, that there is significant heterogeneity in this outcome depending upon the own-price elasticity of demand for forest products and, as a result, the trade intensity of the forestry sector. The potential for beneficial effects of plantation expansion on un-harvested natural forests is diminished in countries with trade-oriented forestry sectors (Heilmayr, 2014).

2.7.4 Methods used to study the effects of altitude and slope aspects on plant characteristics

Population census of Pygymy tarsiers was conducted across various altitudes (Grow *et al.*, 2013). Sampling took place within 1.2 km² area encompassing altitudes of 2,000-2,300m.a.s.l on Mt. Rore Katimbu. Grow *et al.*, (2013) observed 22 individuals, with an approximate population density of 92 individuals per 100 ha. The results indicated that Pygymy tarsiers live at a lower density than lowland Sulawesian tarsiers species. Lesser densities were associated with decreased resources at upper altitudes, including decreased tree size, tree density and insect biomass (Grow *et al.*, 2013). Sharma *et al.*, (2010) conducted a study in seven natural forest types of temperate zone of Humalaya in order to determine the effects of slope aspects i.e., north-east (NE), north-west (NW), south-east (SE), and south-west (SW), on the structure, composition and soil characteristics of selected forest types.

A stratified random approach was used to lay out the sample plots. To elucidate the differences in forest structure and composition of forest types the indices such as the Importance value Index, Shannon-Wiener diversity index were calculated. The results showed that the higher values of total basal cover in the forest were recorded in the northern aspects (Sharma *et al.*, 2010).

CHAPTER 3: METHODOLOGY

This chapter presents the methods that were used for data collection and analysis. Analysis of aerial photographs and field surveys were used to study forest edge movement. Six sampling sites showing different physiographic and plant characteristics were identified in the Dontsa FMU for data collection purposes. Each sampling site was selected for a specific objective based on the characteristics that were observed during preliminary survey.

3.1 Assessment of the scale of forest edge movement

To assess the scale of forest edge movement, the trends of forest ecotone changes were studied by analysing aerial photographs using ArcGIS version 10. In this study, georeferenced aerial photographs of the years 1975, 1985, 1992, 2002 and 2014 were used. The aerial photographs were sourced from the Department of Rural

Development and Land Reform of the Republic of South Africa for the purpose of this research. The boundary of the forest was digitized in all the aerial photographs to study the trends of forest edge movement from the year 1975, 1985, 1992, 2002 to 2014. Created polygons were superimposed to determine the scale of forest edge movement in all the research sampling sites. Naturally, the movement of a forest edge adopts an irregular pattern. As a result, at least three measurements were obtained from different points at each sampling site to determine the average distance of forest edge movement. The patterns of forest edge movement were analysed to show trends from 1975 to 1985, 1975 to 1992, 1975 to 2002, 1975 to 2014, 1985 to 1992, 1985 to 2002, 1985 to 2014, 1992 to 2002, 1992 to 2014 and 2002 to 2014.p-

3.2 The relationship between plant species density, species richness and forest edge movement

To determine the relationship between plant species frequency, species richness and forest edge movement, plant sampling was conducted in all research sites by establishing a belt transect of 5m by 100m which extended 20m from the forest border into the forest and 80m from the border into the exterior of the forest. The plant characteristics studied included plant species frequency and plant species richness. The rationale behind the use of a belt transect of 5m by 100m for plant data collection is that belt transects have proven to be effective in previous similar studies. In addition, the size of the belt transect was tested during the preliminary survey and found to be appropriate to collect data for the purpose of this study. The results obtained on plant species frequency and species richness were used together with the results obtained for the assessment of forest edge movement to determine the relationships between species frequency, species richness and forest edge movement.

3.2.1 Plant species density

The names of plant species that occur in the belt transect were identified to determine the species composition of the six research sites. The Trees of Natal Field Guide (Pooley, 1994) was used to identify the botanical names of plants. The understory, subcanopy and canopy plants were identified in the established transects. The species density was determined by calculating the number of individual plants species per 10m x 5m quadrat. The density of individual plant species that were in each quadrat of 5m x10m were determined using Equation 1(Eq) from the interior to exterior of the forest and Pearson's correlation statistical model was used to assess the level of relationship between forest edge movement and plant species density.

$$D = \frac{\text{number of individual plant species}}{m^2} \qquad \text{Eq. 1}$$

(Muthulingam and Thangavel, 2012)

3.2.2 Plant species richness

Through plant data analysis plant species richness were determined in the portions of the transect. The species richness was determined by counting the number of different plant species in all the quadrats of 10m x 5m in size within the established belt transects in relation to forest edge movement of research site 3 and 5. Plant data on species richness was analysed to determined weather species richness increases or decreases from the forest interior to exterior and the data generated was correlated with forest edge movement using Pearson's statistical model.

$$R = \frac{\text{number of plant species}}{m^2} \qquad \text{Eq.2}$$

(Muthulingam and Thangavel, 2012)

3.3 The effects of altitude, slope angle and orientation on forest edge movement

3.3.1 Determination of the slope altitude

The slope altitude was determined using a Global Positioning System (GPS) in research site 5 and 6 (Fig. 2) in order to determine the relationship between slope altitude and forest edge movement. The results obtained from the assessment of forest edge movement were correlated with the data obtained in this section to determine how the slope altitude influence forest edge movement.

3.3.2 Determination of the slope angle

Study site 5 and 6 (Fig. 2) was selected to study how slope orientation influences movements of the forest edge. The slope angle was selected as one of physiographic elements of the site to determine how it relates to forest edge movement. It was measured using a clinometer in research site 5 and 6 from two aspects of the sampling site. Results from the assessment of forest edge movement were correlated with the results obtained from slope angle measurements to determine how slope angle influences forest edge movement.

3.3.3 Determination of the slope orientation

The slope orientation was determined during sampling in research site 5 and 6. It was captured using a GPS. This data obtained was used together with the data obtained in the assessment of forest edge movements to determine the relationship between slope orientation and forest edge movement.

3.4 The effects of cutting of indigenous trees and harvesting of Pinus patula on forest edge movement

3.4.1 Effects of cutting of indigenous trees on forest edge movement

The effects of cutting trees on forest edge movement was assessed by identifying stumps and determining the number of stumps and the species names of all trees that were cut within a 5m x 100m belt transect at sampling site 1 (Fig. 2). The diameter of each stump was measured using a measuring tape. The data was used to study the relationship between forest edge movement and anthropogenic activities.

3.4.2 Effects of harvesting of Pinus patula on forest edge movement

To investigate the effects of harvesting *Pinus patula* plantation trees on the forest edge movement, the seedlings and tree species density was determined at sampling site 4 (Fig. 2). *P patula* is the plant species planted in the commercial forestry plantation adjacent to Dontsa indigenous forest patch. The plant species density was determined by establishing a belt transect of 100m by 5m from the interior of the forest to the buffer zone of the forest. The species density data was then generated by analysis of plant sampling data in each quadrat. The number of individual plant species were calculated per quadrat to determine the density of each plant species in the transect (Eq.1).

3.5 Summary of research sites characteristics

Table 2. Research sites characteristics

Research site	**Key characteristics**
1	The site was characterized by cutting of trees along the forest edge and it was selected to address research question (d).
2	Research site 2 was characterized by high frequency of fire and it has a wetland in the grassland within the forest. The site was selected to address research question (a).
3	Research site 3 was characterized by high abundance of indigenous seedlings forming the forest ecotone. Due to high vegetation cover extending towards the grassland the site was selected to address research question (b).
4	Research site 4 is located adjacent to *P patula* plantation trees on the steep mountainous escarpment of Amathole.

	The site was selected to address research question (d).
5	Research site 5 is located in the catchment area and this site has south east and south west aspect hence it was selected to address research question (c).
6	Research site 6 has south east and south west aspect with high abundance of woody species growing the buffer zone. The site was selected to address research question (c) due to the presence different physiographic elements .

CHAPTER 4: RESULTS

This section provides results based on the analysis of aerial photographic data and field survey data which was collected in relation to specific objectives of this research. Graphs, tables and maps are used to present the results.

4.1 Assessment of the scale of forest edge movement

The diagrams illustrated below demonstrate patterns of forest edge movement over time from 1975, 1985, 1992, 2002 to 2014 at six research sites located in Dontsa FMU. Figures 3 to 8 and Tables 1 to 2 present data on forest edge movement, generated from measurement of digitized geo referenced aerial images.

4.1.1 Forest edge movement at research site 1

At research site 1 from 1975-1985 the analysis of forest edge movement data exhibits negative forest edge movement (Table 3). The general trends show that the forest edge has experienced a negative movement (-197.30m) over the years from the year 1975 to 2014. Evidence of positive forest edge movement was observed between the years 2002 and 2014.

Table3. Average distance (m) of forest edge movement over time at sampling sites

Period	Research sampling sites					
	1	2	3	4	5	6
1975-1985	-24.70	34.7	5	2.6	-17.1	19.3
1975-1992	-104.30	-37.3	32	-28.5	54	17.5
1975-2002	-130.30	-30.2	16.5	65	70.5	32
1975-2014	-197.30	-36.2	45.7	-60.5	10.6	36
1985-1992	-63.00	-32.6	29.5	-8.6	38.2	5.1
1985-2002	-128.4	-36.4	18.3	57.6	52	24.5
1985-2014	-165.4	-40.5	23.4	-78	68.7	33

1992-2002	-22.70	72	9	79.2	24.5	15
1992-2014	-2.1	24.5	21.6	-79.4	45.1	47
2002-2014	3.6	2	45.7	-79.7	10.6	24.5
Net movement	-834.6	-80	246.7	-130.3	357.1	253.9

The positive number in the table represents positive forest edge movement while the negative number represents negative movement of the forest edge.

Table 4. Change in forest cover (m²) at sampling sites resulting from forest edge movement

Period	Research sampling sites					
	1	2	3	4	5	6
1975-1985	-1491.40	7 185	1 681	1 985.8	-13 833	2 652.2
1975-1992	-75031.70	-41 239	3 269.6	-4 844	9 841.4	2 550.2
1975-2002	-530 678.6	-14 338.3	8 281	40 891.3	12 585.8	16 762
1975-2014	-192986	-1 062	1 313	-159 457.6	872.4	39 456
1985-1992	-204852.80	-82 274	2 638	-1 426	33 470.71	545
1985-2002	-300 893	-34 410	8 883	38 600	36 721.2	13 569

1985-2014	-158 451.5	-9 904	7 876.5	-329 960	40 132.5	22 500
1992-2002	-17738.60	5 072	732.5	41 060.8	3 249	13 572.2
1992-2014	-9 161.5	48 499	11 990	-154 733	41 353	23 639
2002-2014	9 779	11 043	1 313	-150 597	872.4	13 569
Overall change	-148 1506.1	-111 428	47 978	-678 479.70	165 265	148 814.60

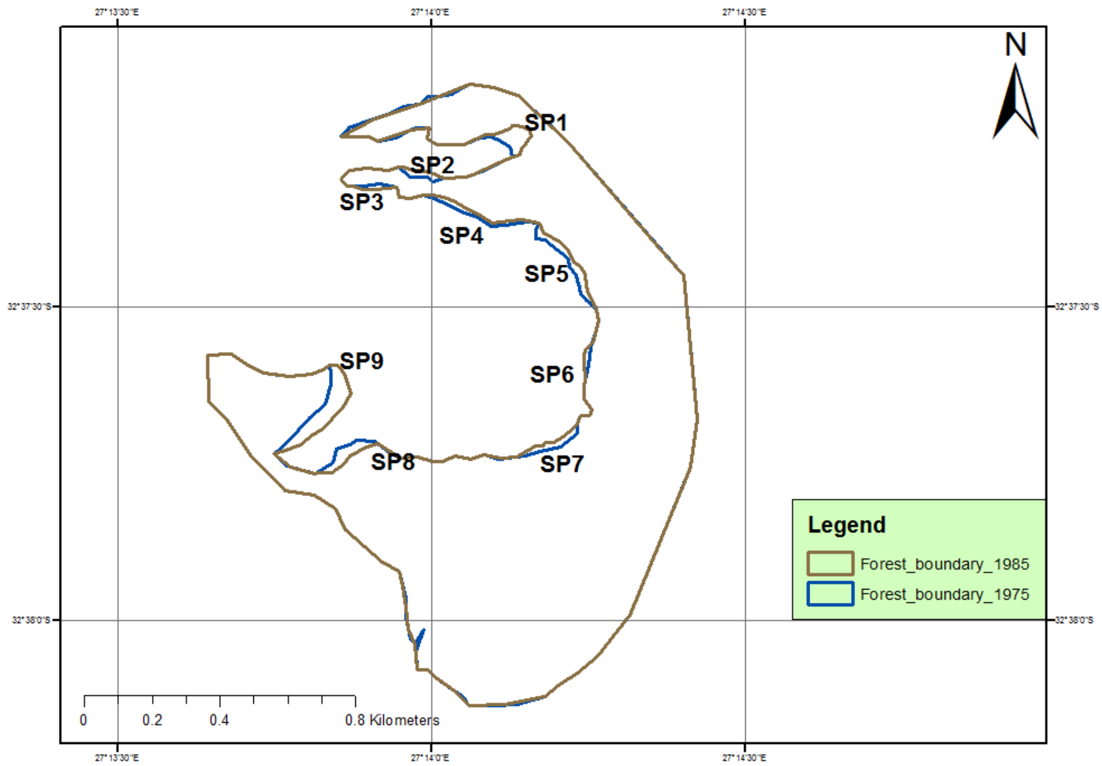

Figure 3a. Forest edge movement in research site 1 from 1975-1985

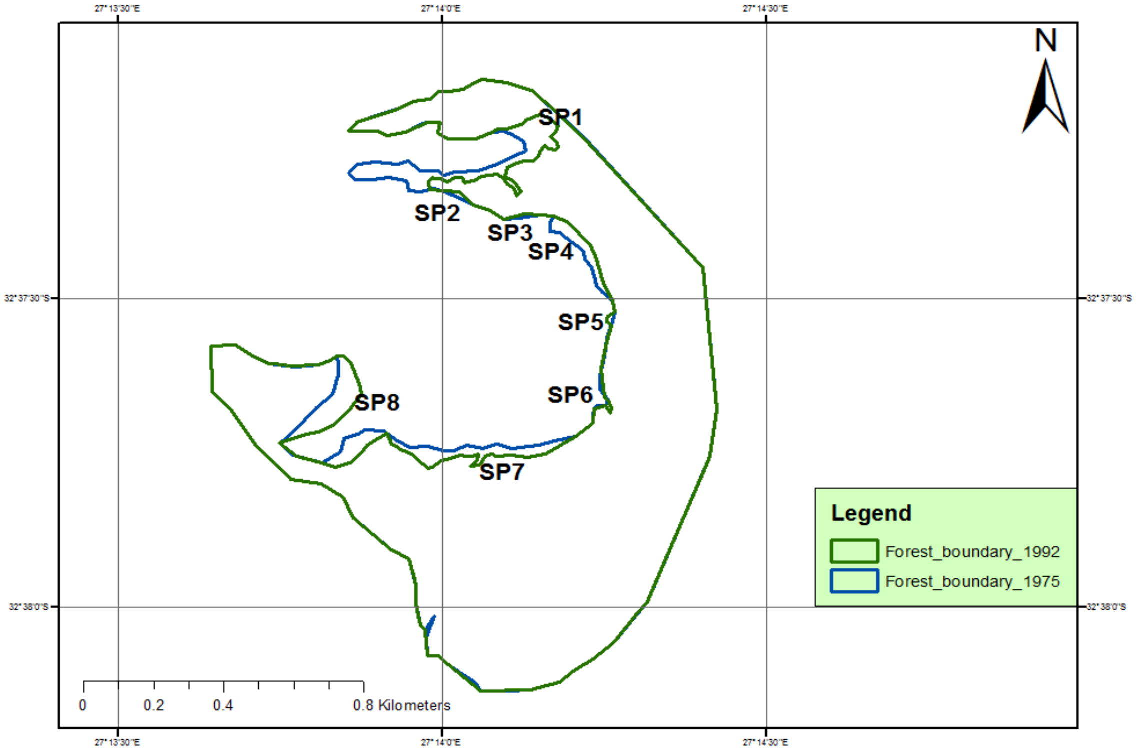

Figure 3b. Forest edge movement in research site 1 from 1975-1992

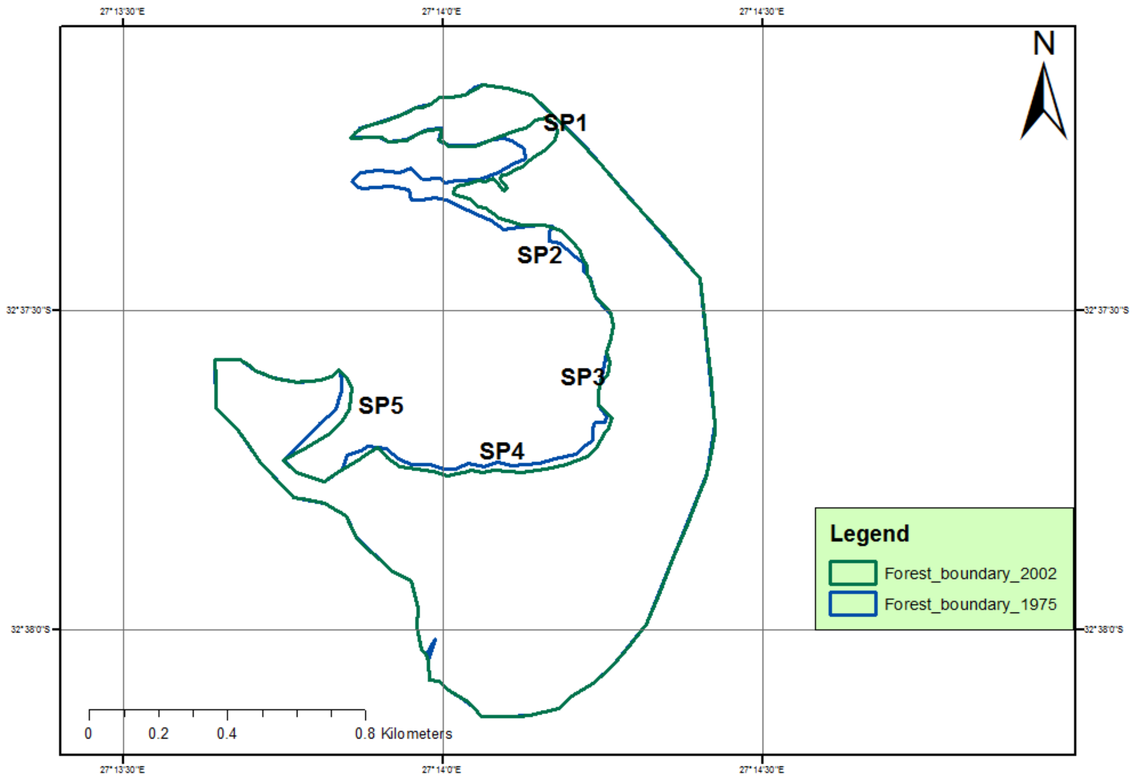

Figure 3c. Forest edge movement in research site 1 from 1975-2002

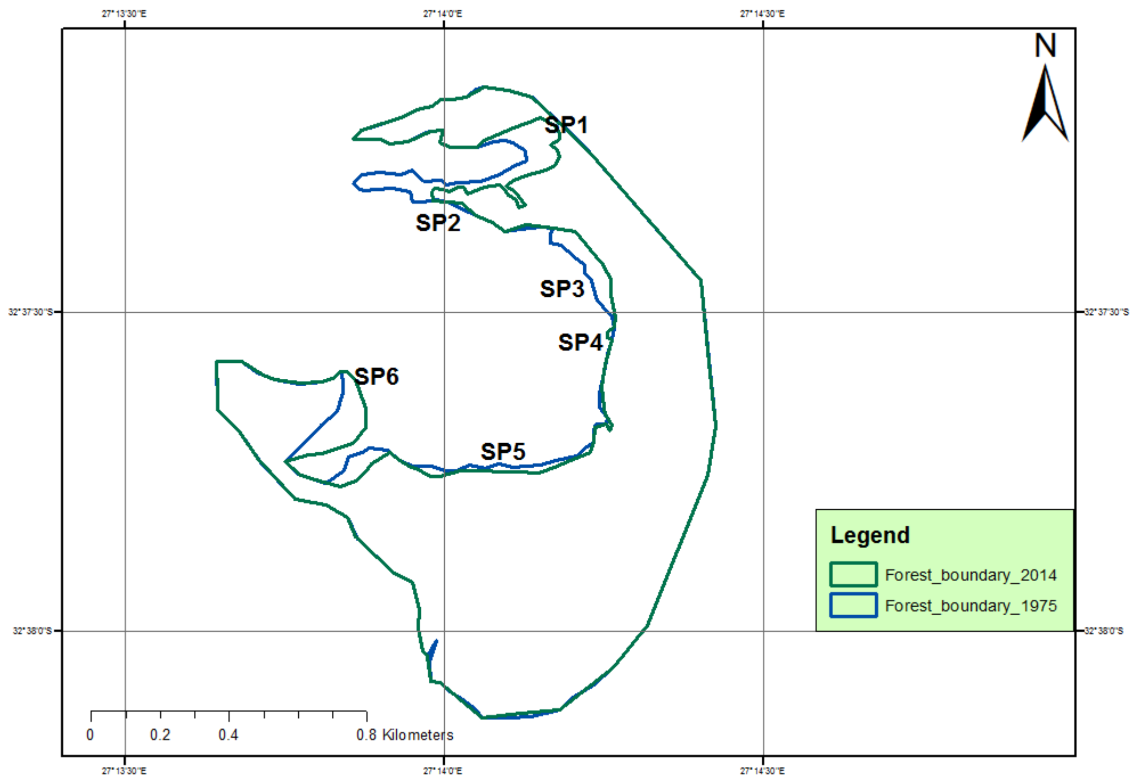

Figure 3d. Forest edge movement in research site 1 from 1975-2014

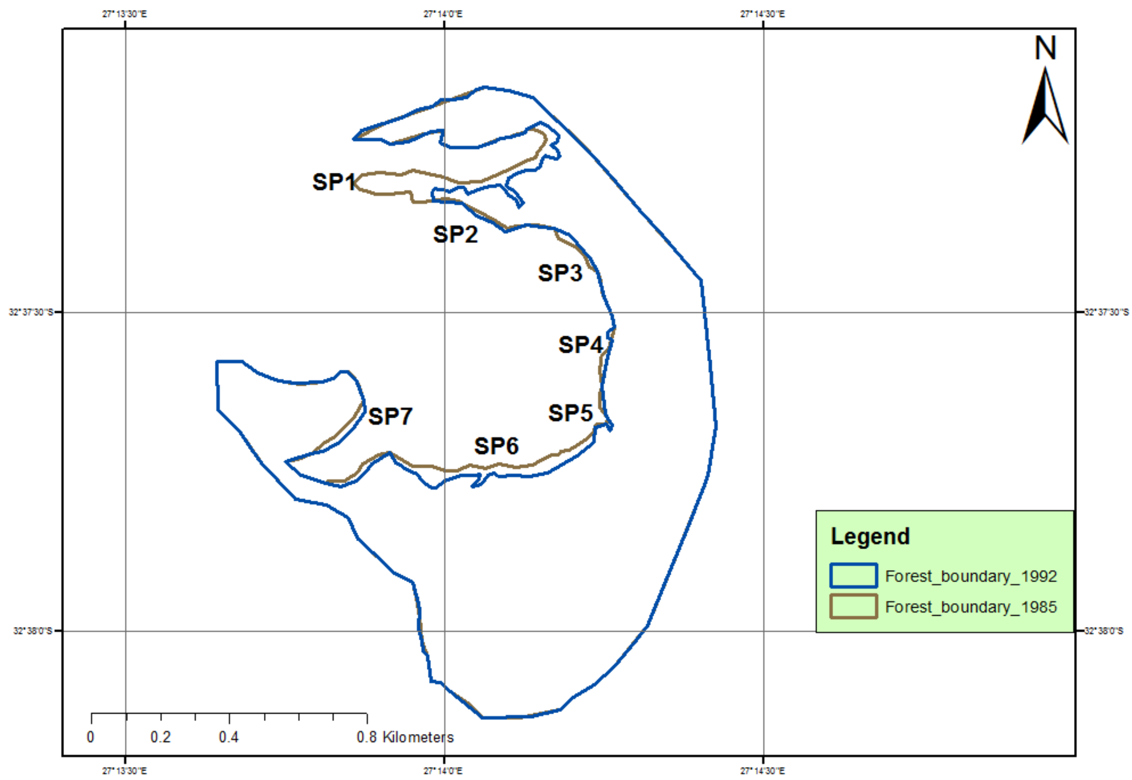

Figure 3e. Forest edge movement in research site 1 from 1985-1992

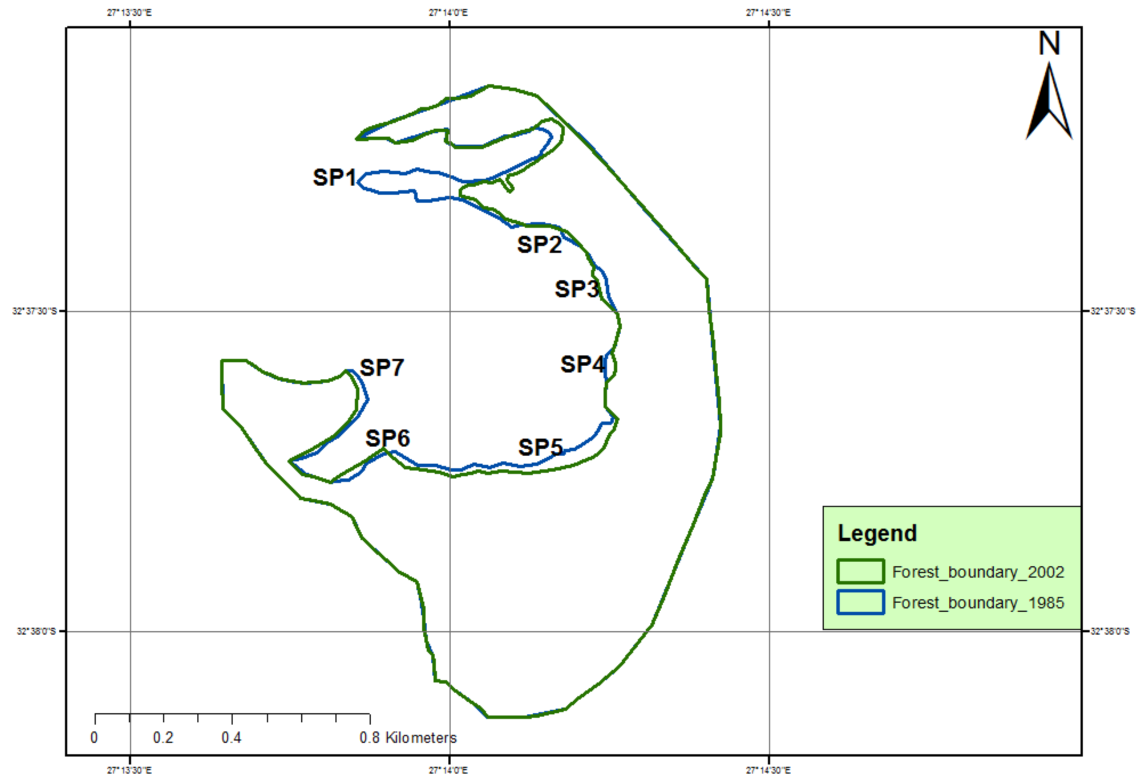

Figure 3f. Forest edge movement in research site 1 from 1985-2002

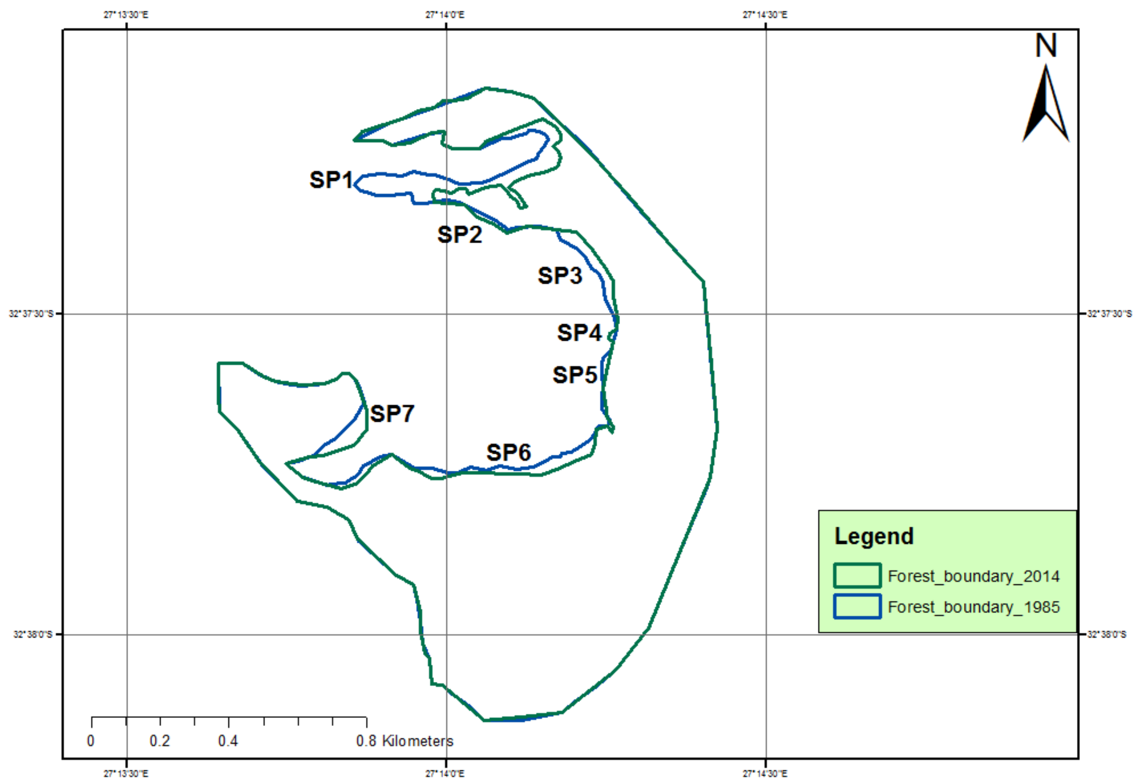

Figure 3g. Forest edge movement in research site 1 from 1985-2014

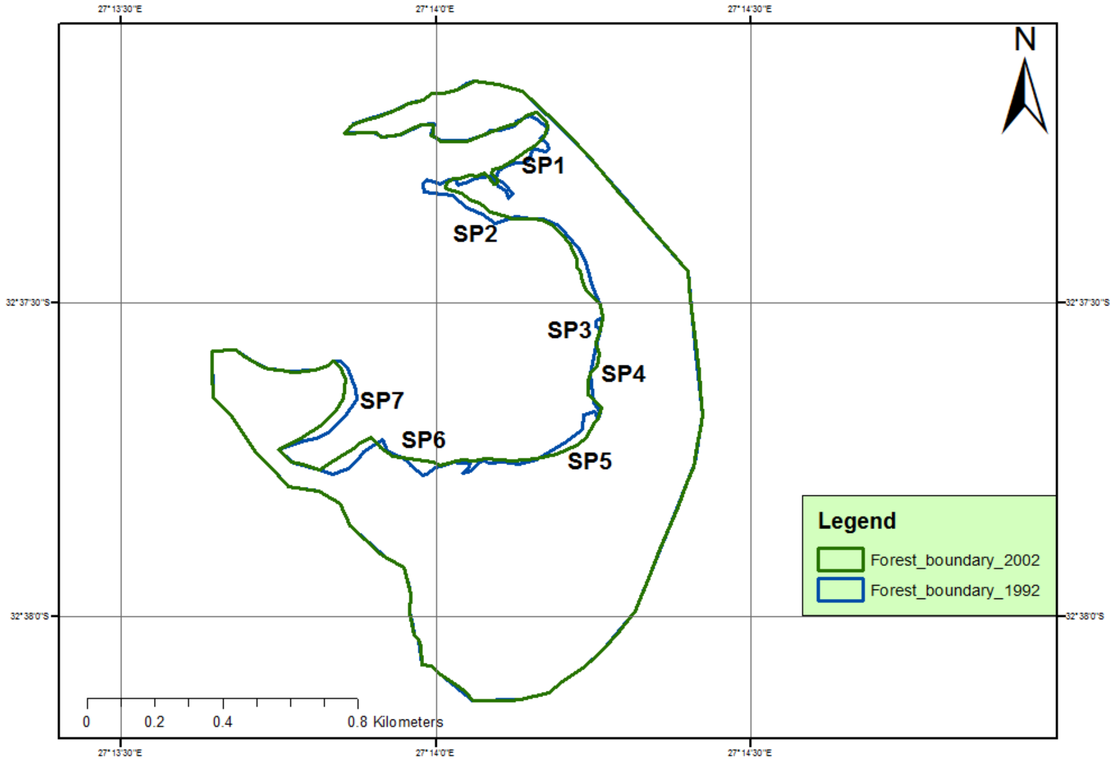

Figure 3h. Forest edge movement in research site 1 from 1992-2002

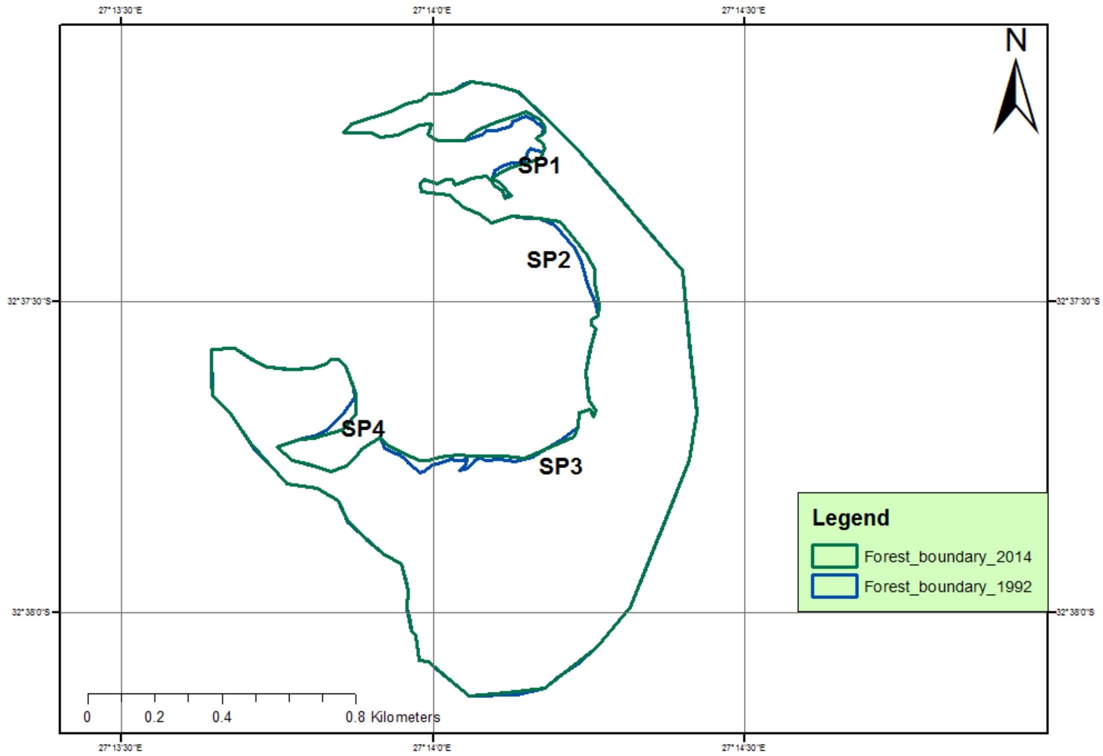

Figure 3i. Forest edge movement in research site 1 from 1992-2014

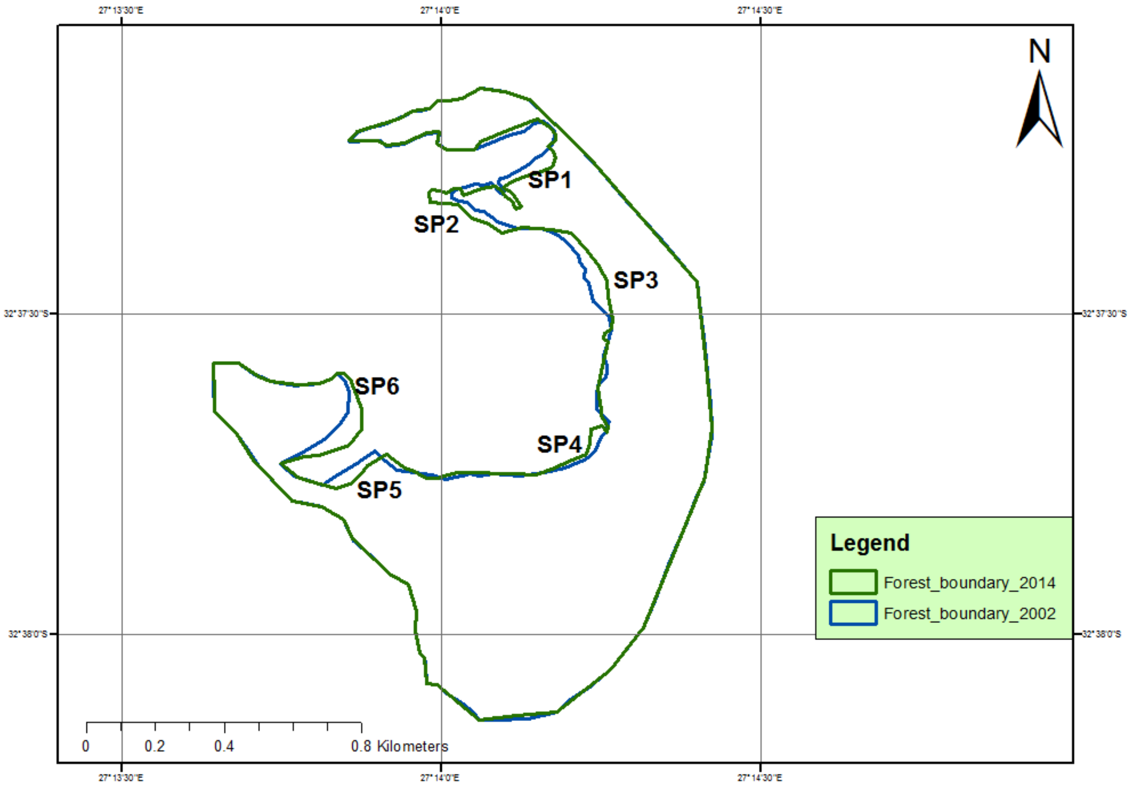

Figure 3j. Forest edge movement in research site 1 from 2002-2014

4.1.2 Forest edge movement at research site 2

Research site 2 demonstrated positive forest edge movement in the past from 1975 to 1985 with 34.7m. After the first interval which is 1975-1985 of the study period there was negative forest edge movement from 1975 to 1992, 1975 to 2002, 1975 to 2014, 1985 to 1992 and 1985 to 2014, (Table 3 and 4). From 1992- 2002, 1992-2014 and 2002-2014 research site 2 demonstrated positive forest edge movement.

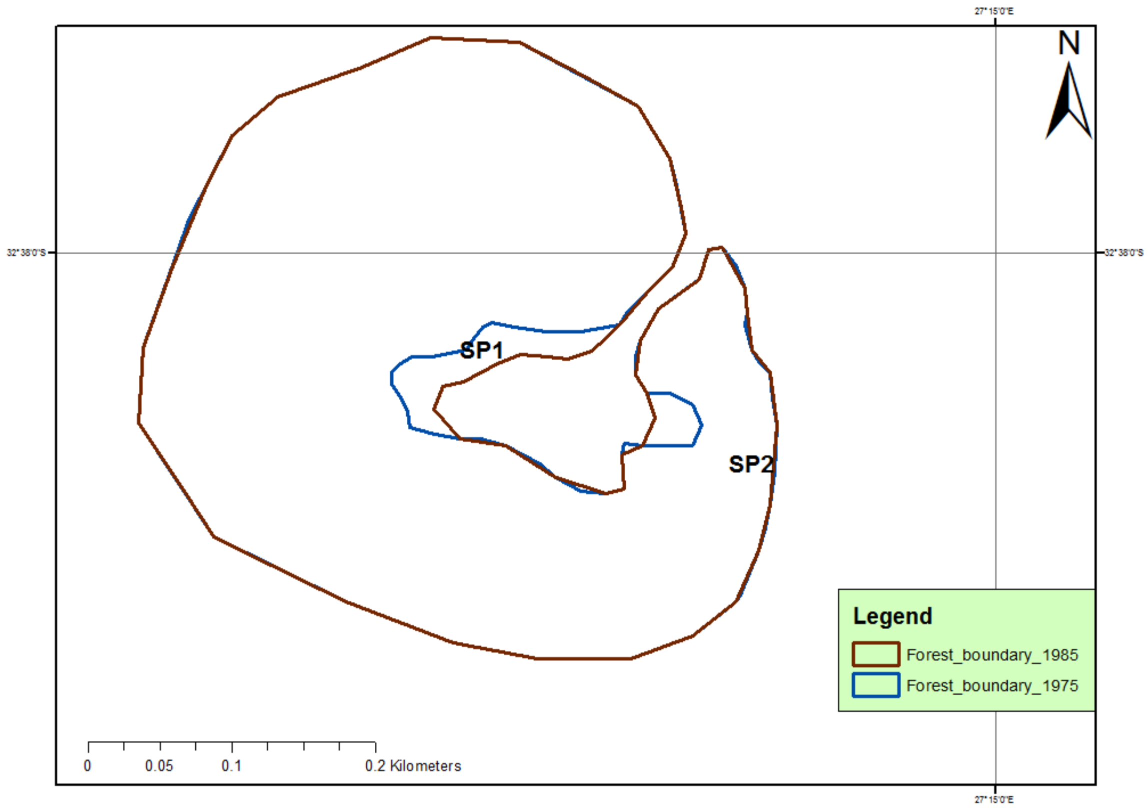

Figure 4a. Forest edge movement in research site 2 from 1975-1985

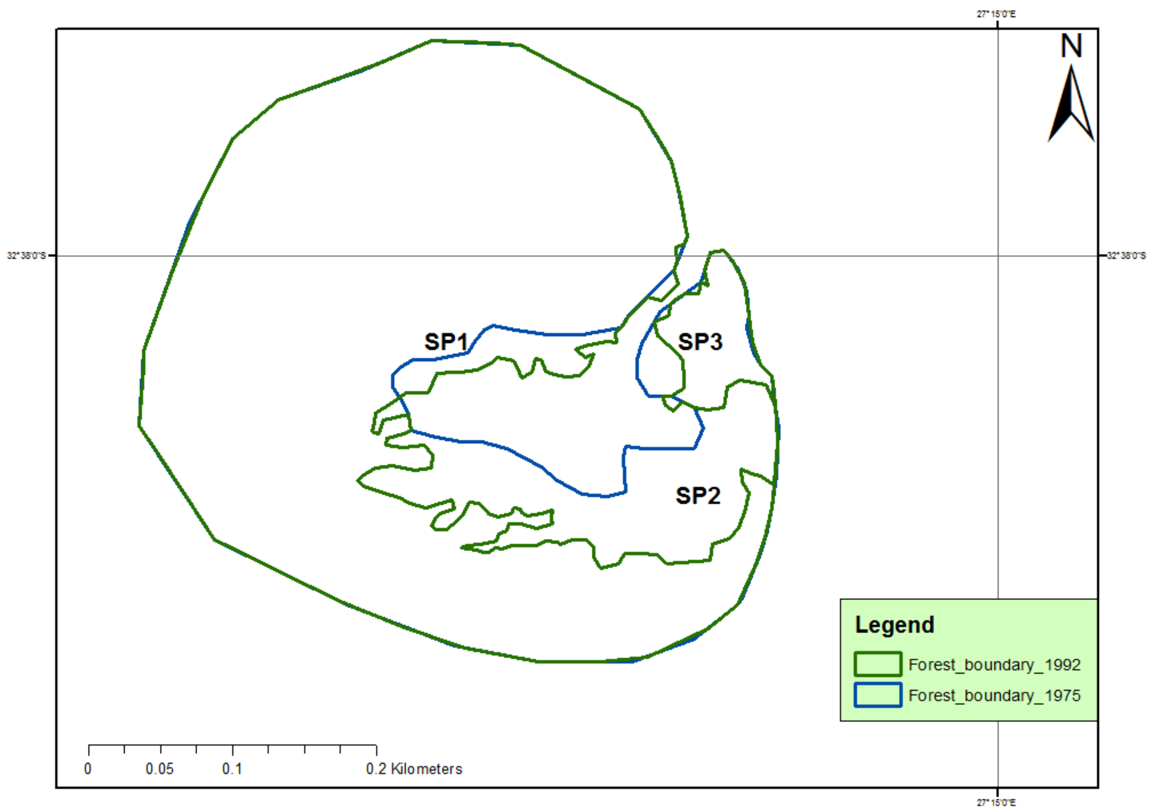

Figure 4b. Forest edge movement in research site 2 from 1975-1992

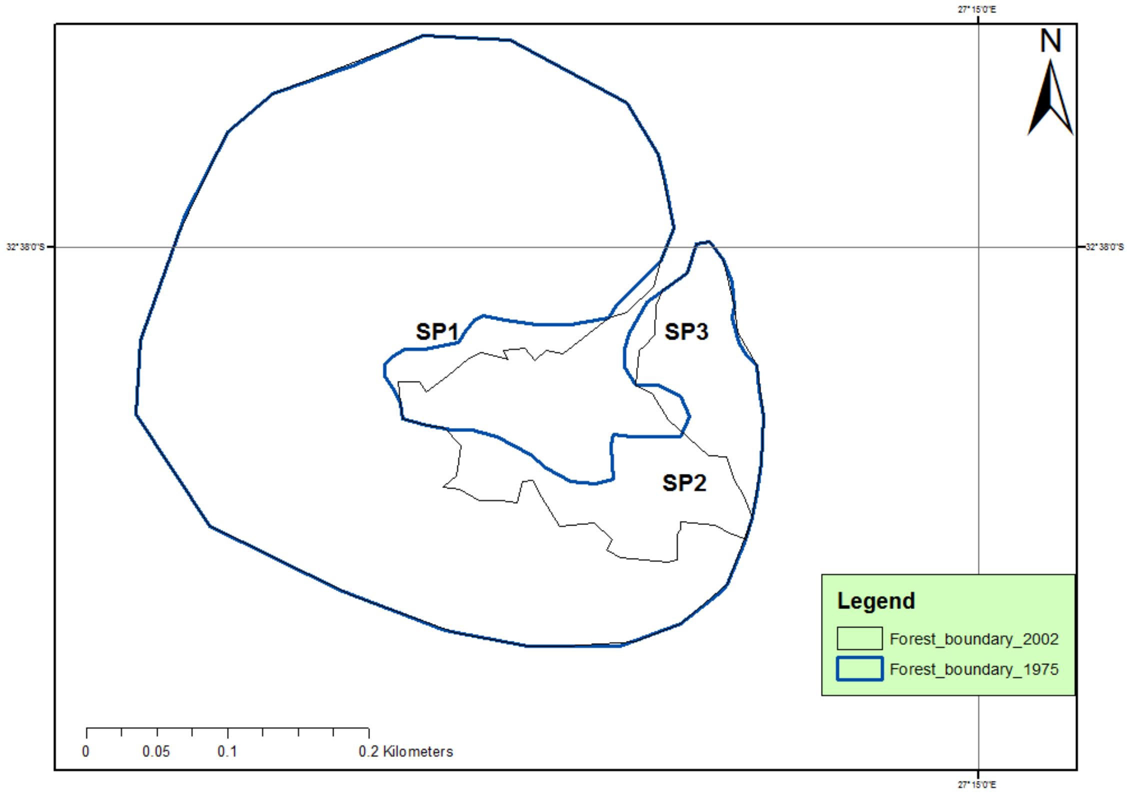

Figure 4c. Forest edge movement in research site 2 from 1975-2002

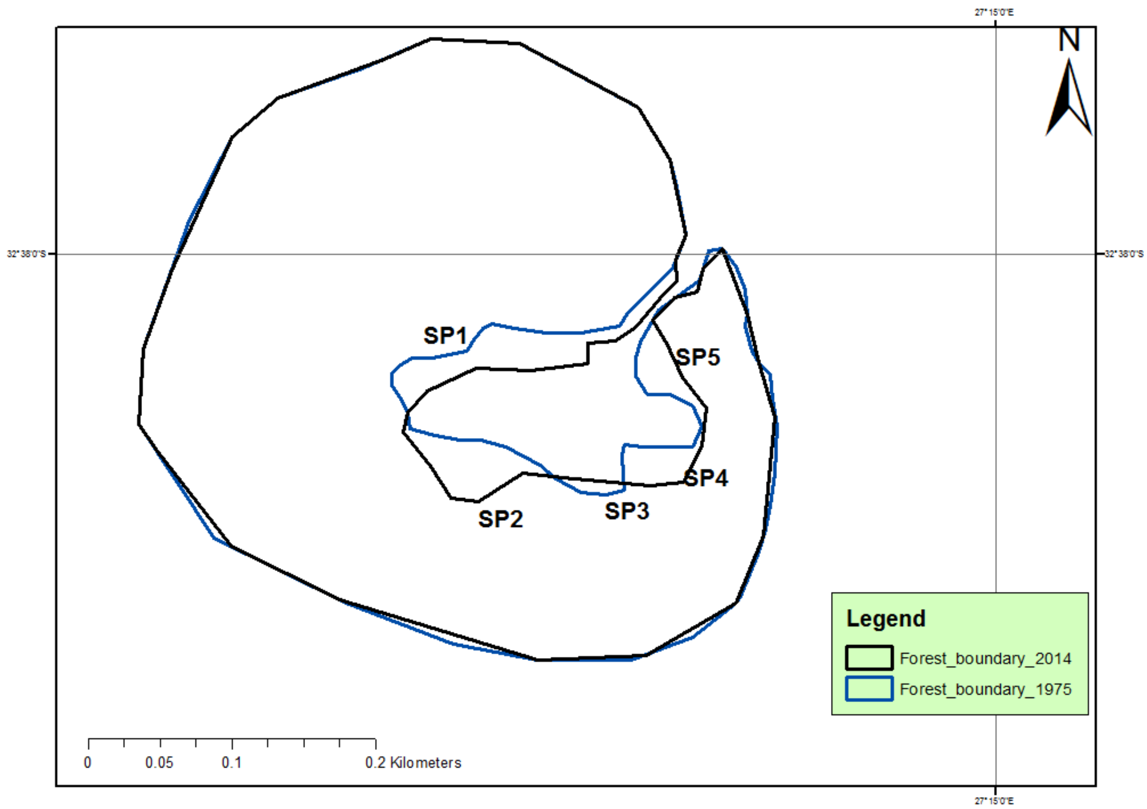

Figure 4d. Forest edge movement in research site 2 from 1975-2014

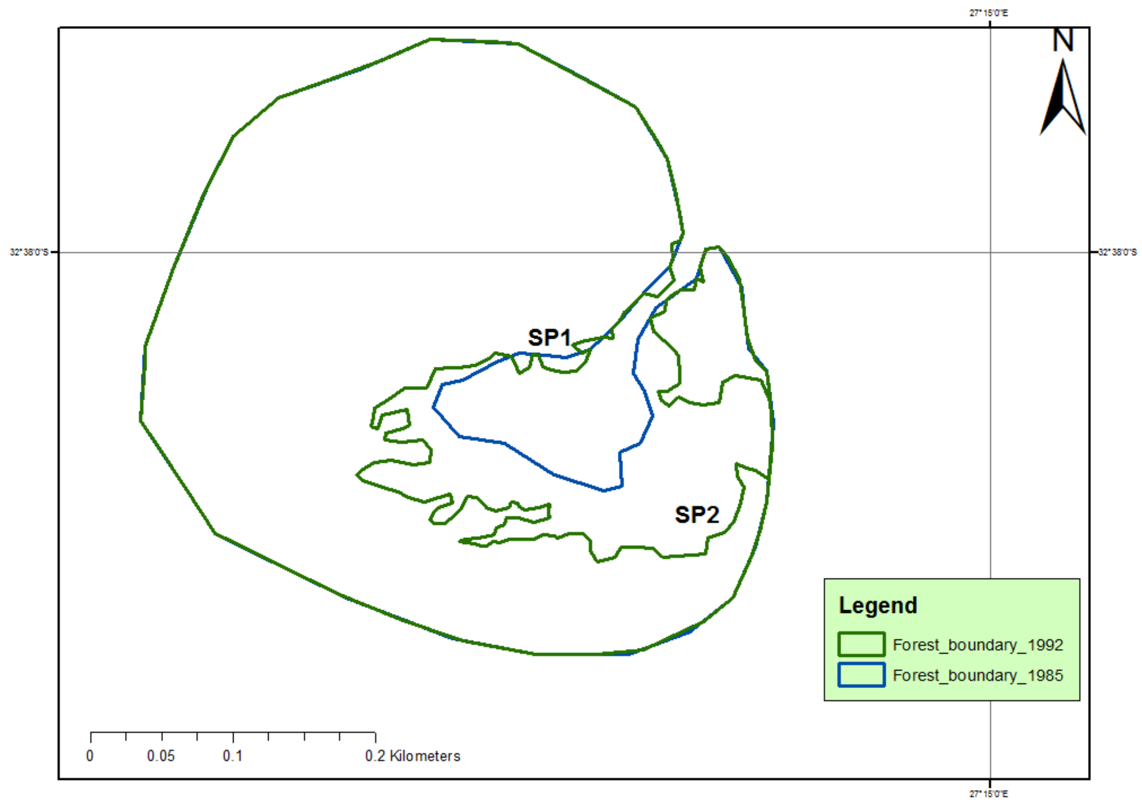

Figure 4e. Forest edge movement in research site 2 from 1985-1992

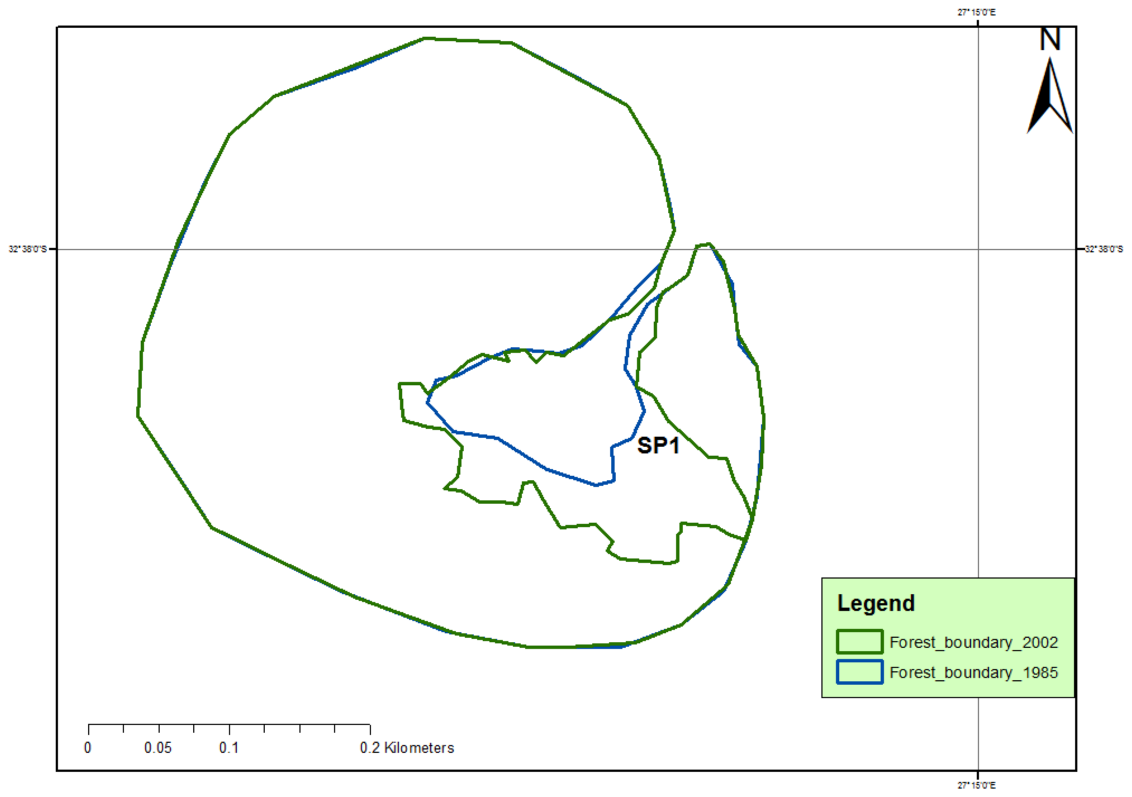

Figure 4f. Forest edge movement in research site 2 from 1985-2002

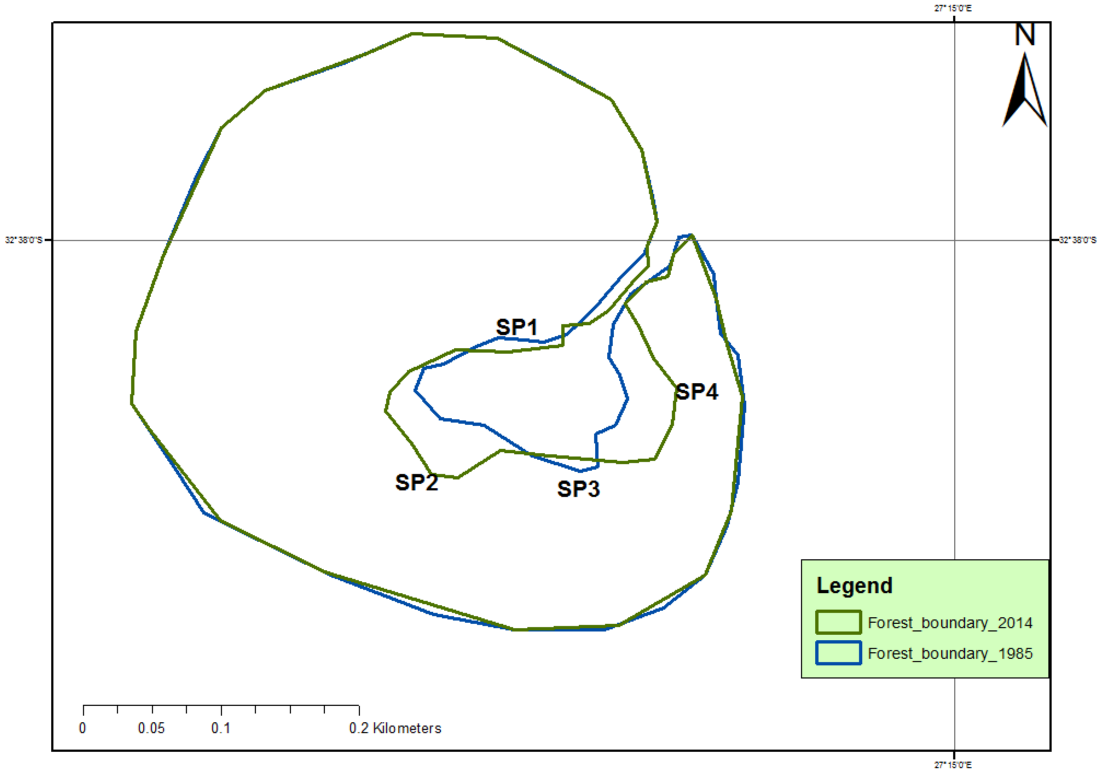

Figure 4g. Forest edge movement in research site 2 from 1985-2014

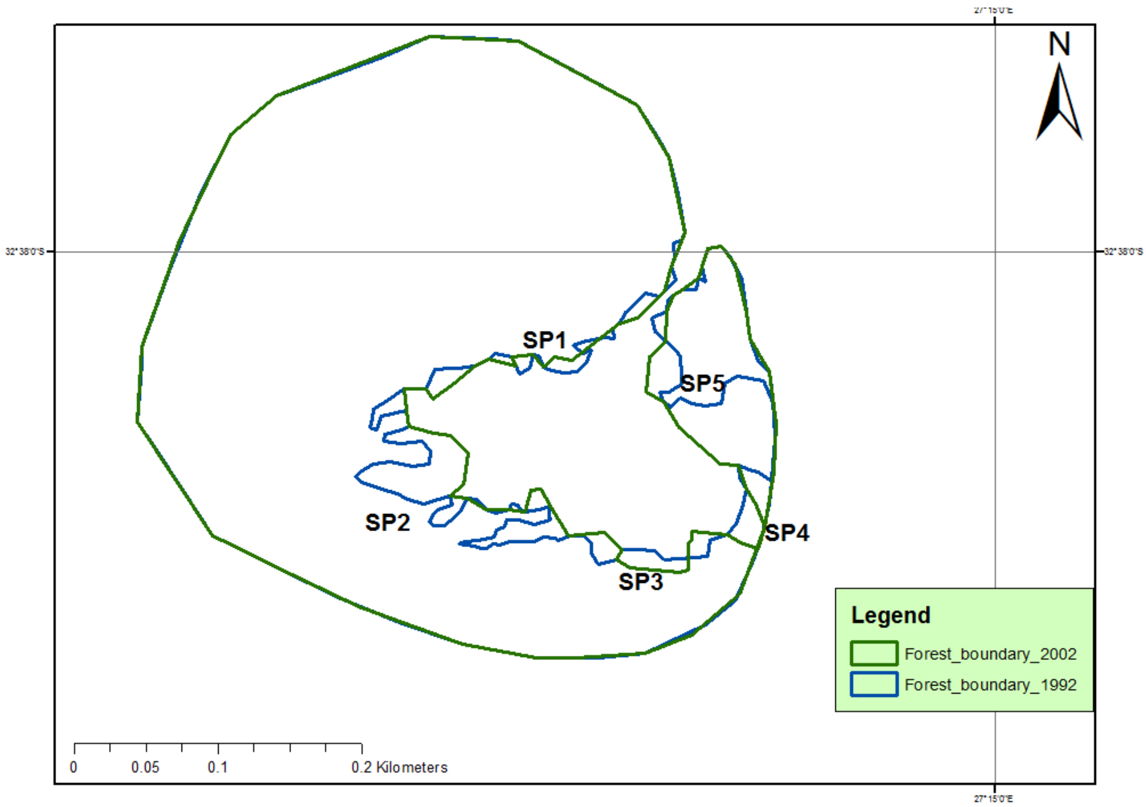

Figure 4h. Forest edge movement in research site 2 from 1992-2002

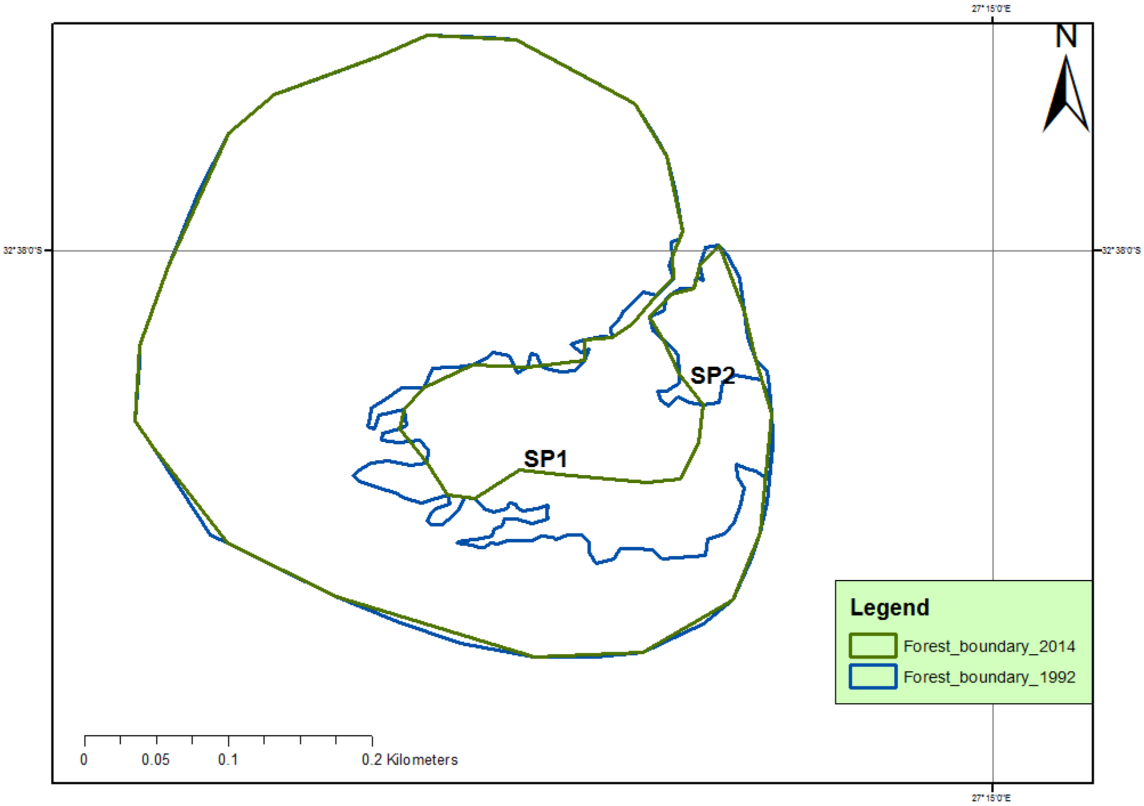

Figure 4i. Forest edge movement in research site 2 from 1992-2014

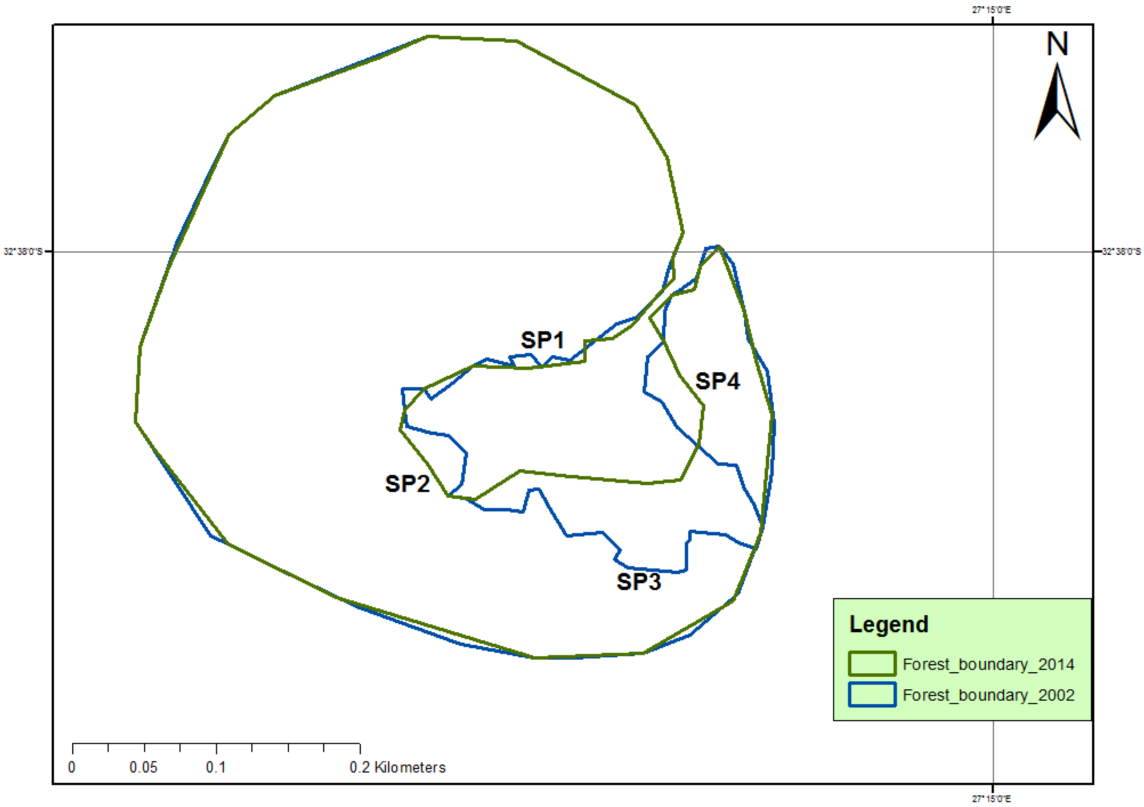

Figure 4j. Forest edge movement in research site 2 from 2002-2014

4.1.3 Forest edge movement in research site 3

Research site 3 showed a positive movement of the forest edge over time from 1975 to 1985, 1975 to 1992, 1975 to 2002, 1975 to 2014, 1985 to 1992, 1985 to 2002, 1985 to 2014, 1992 to 2002, 1992 to 2014 and 2002 to 2014 (Table 3). SP1 of research site 3 in the forest ecotone demonstrated continuous movement of the forest edge from 1975 to 1985 until the latter period of the study which is 2002 to 2014. This is demonstrated by few portions of forest edge movement in the forest ecotone (Figure 5a-j).

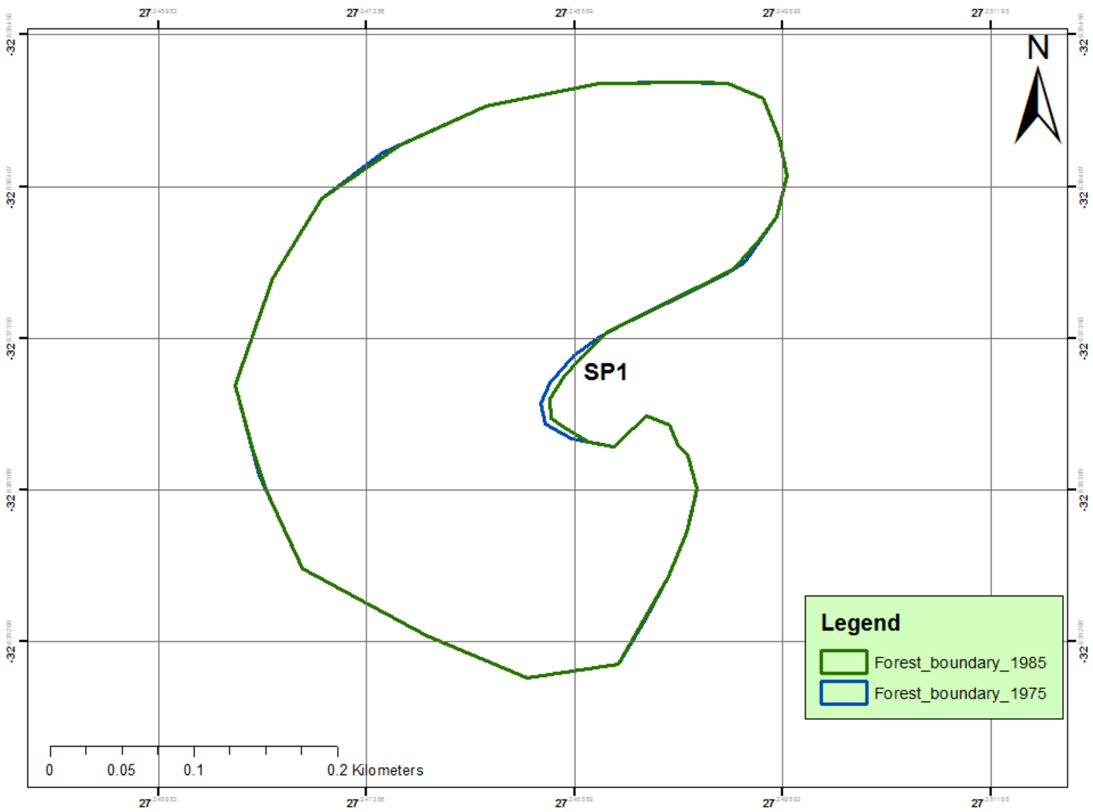

Figure 5a. Forest edge movement in research site 3 from 1975-1985

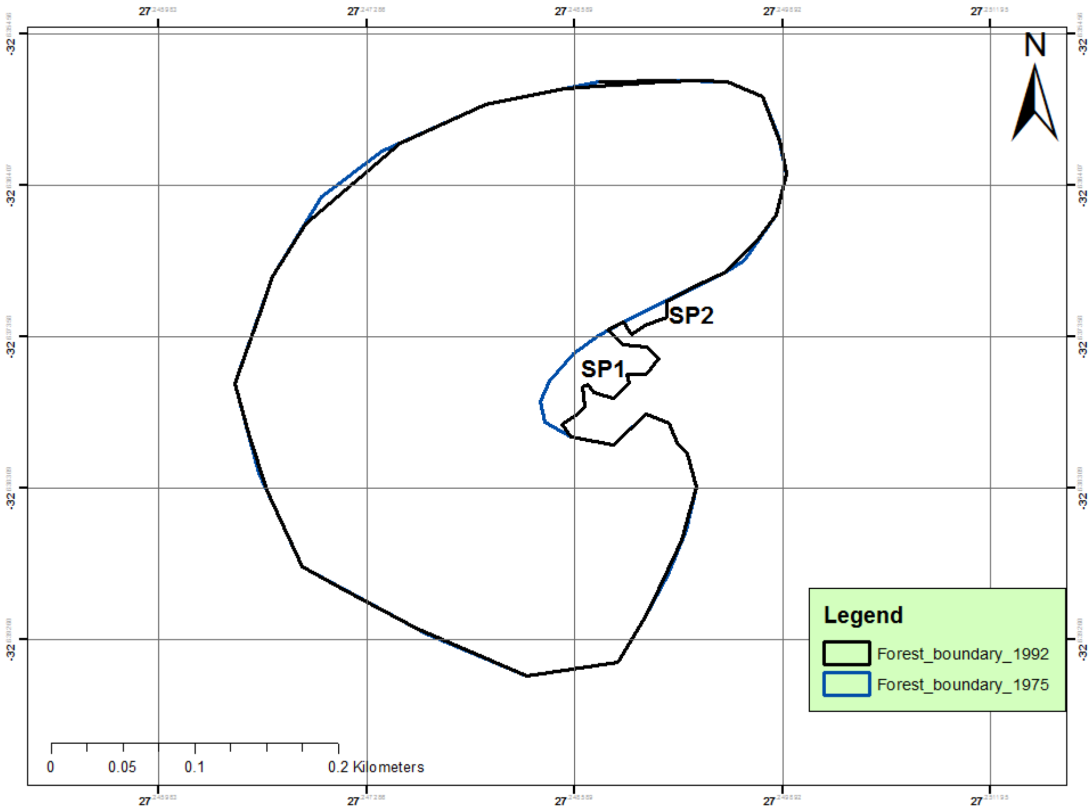

Figure 5b. Forest edge movement in research site 3 from 1975-1992

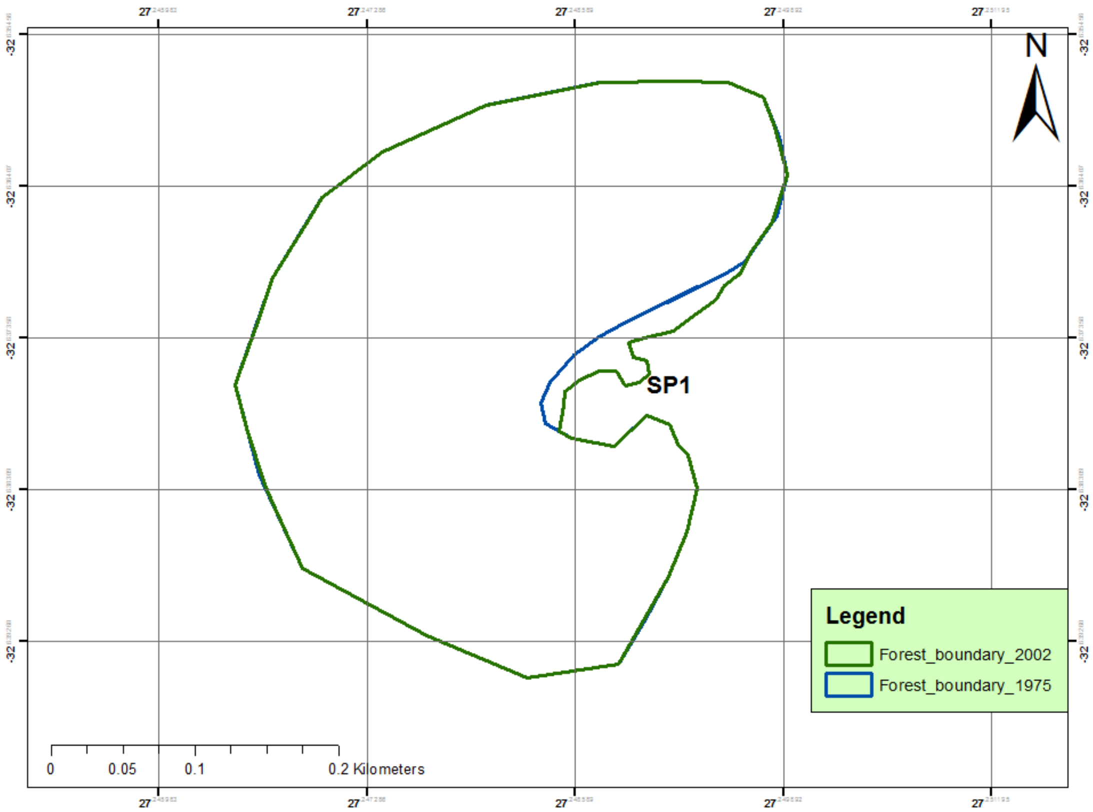

Figure 5c. Forest edge movement in research site 3 from 1975-2002

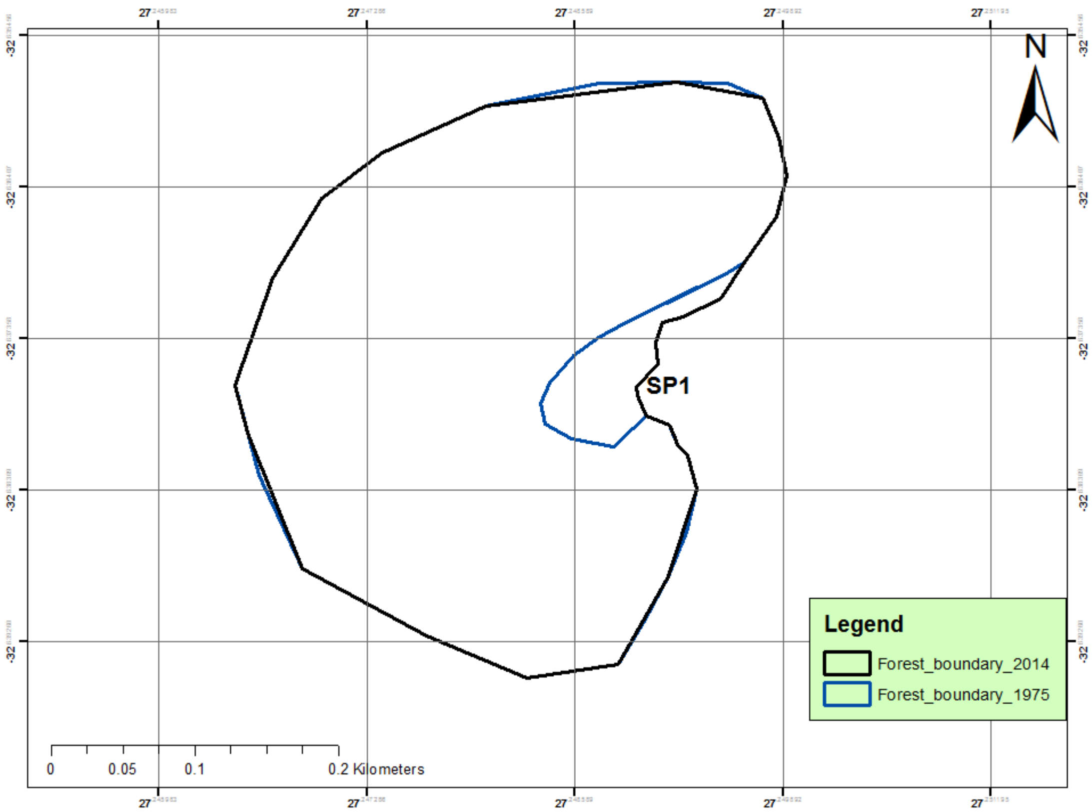

Figure 5d. Forest edge movement in research site 3 from 1975-2014

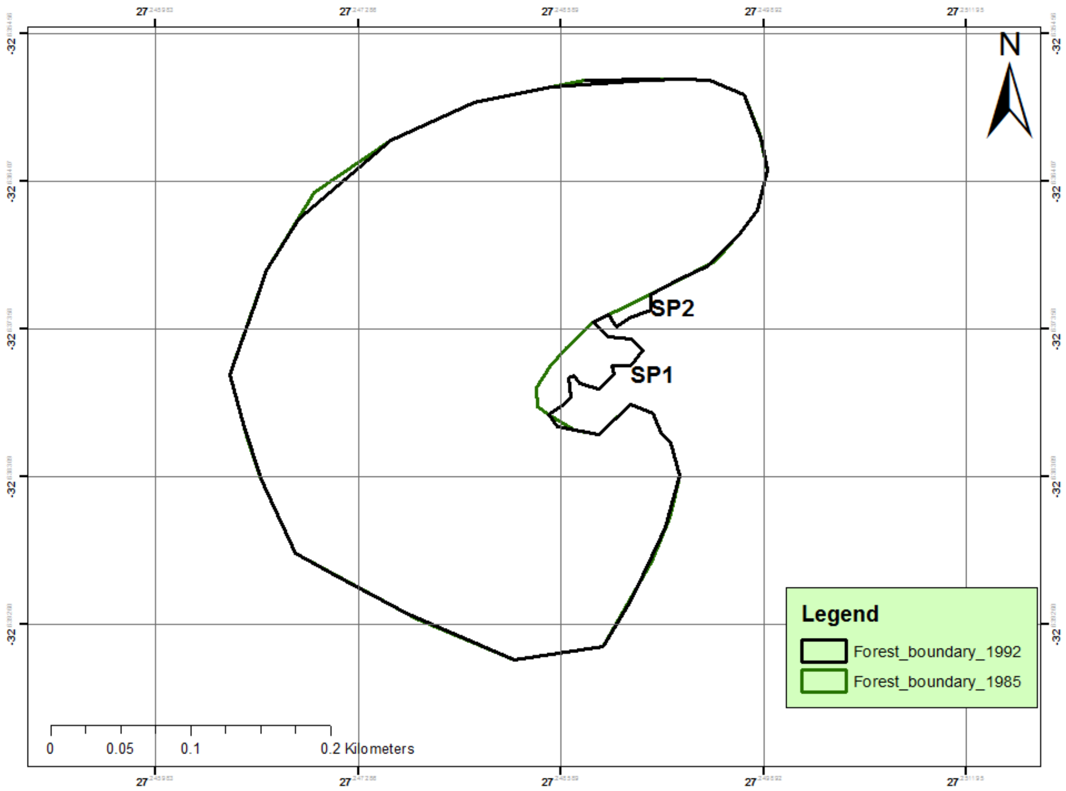

Figure 5e. Forest edge movement in research site 3 from 1985-1992

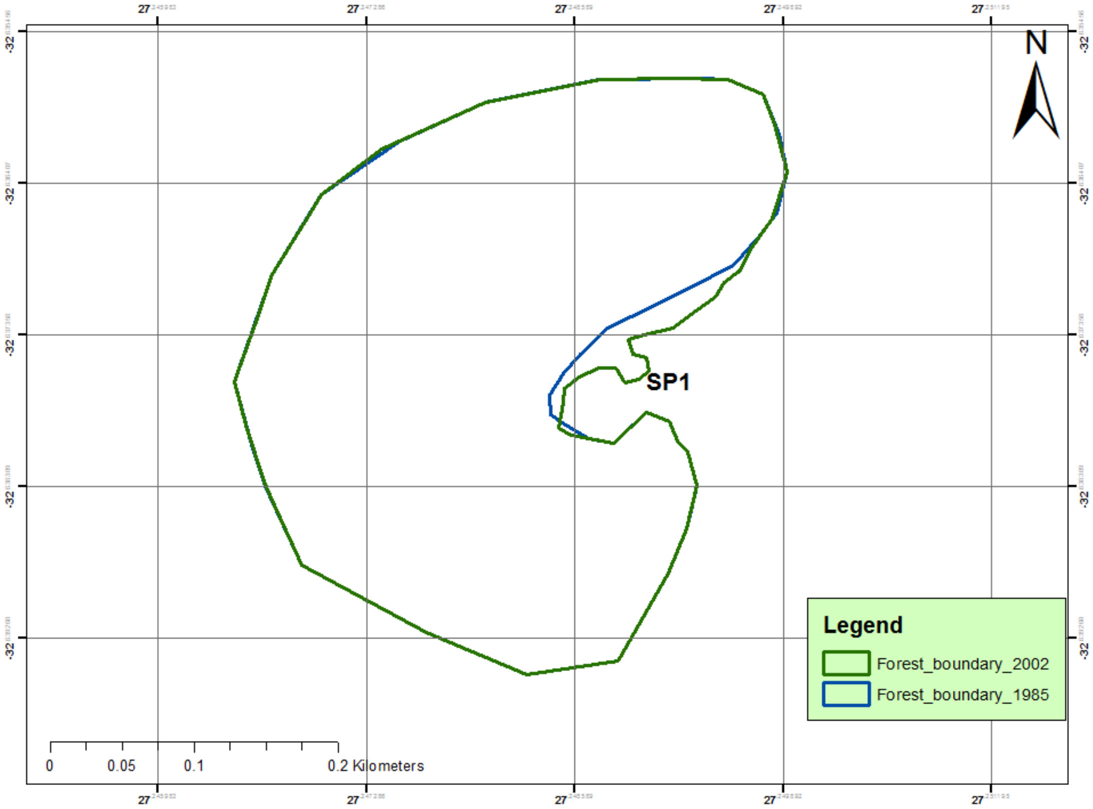

Figure 5f. Forest edge movement in research site 3 from 1985-2002

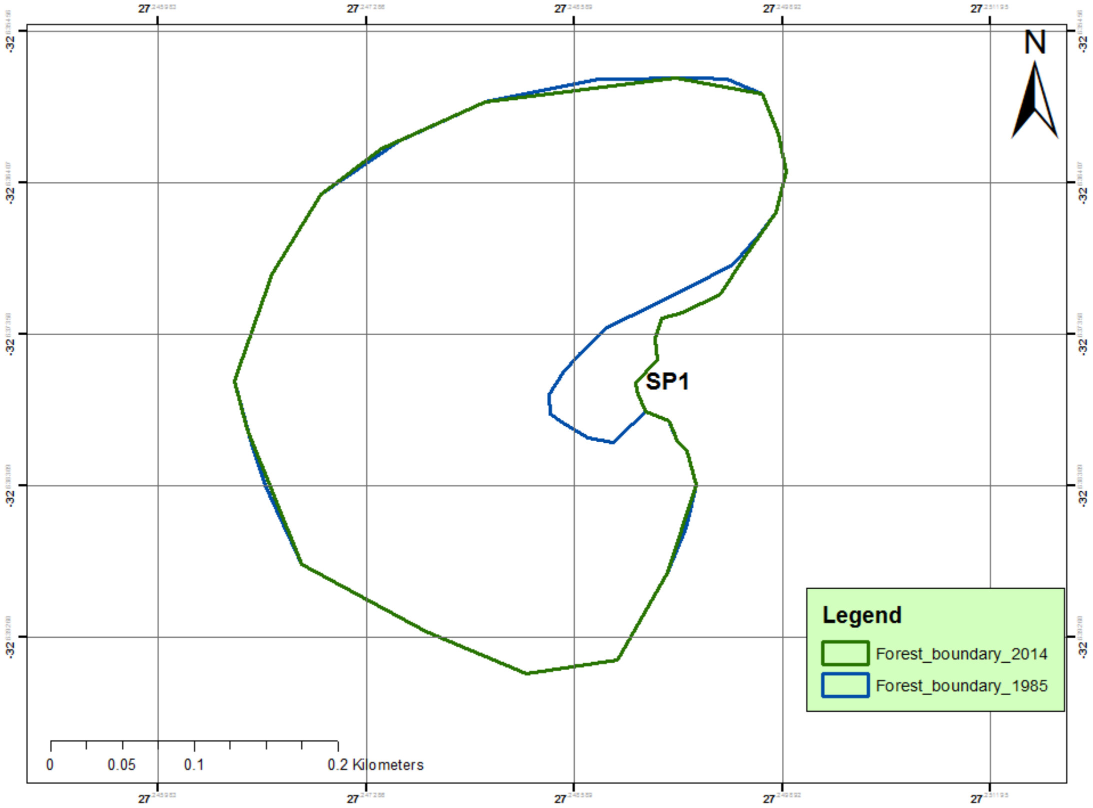

Figure 5g. Forest edge movement in research site 3 from 1985-2014

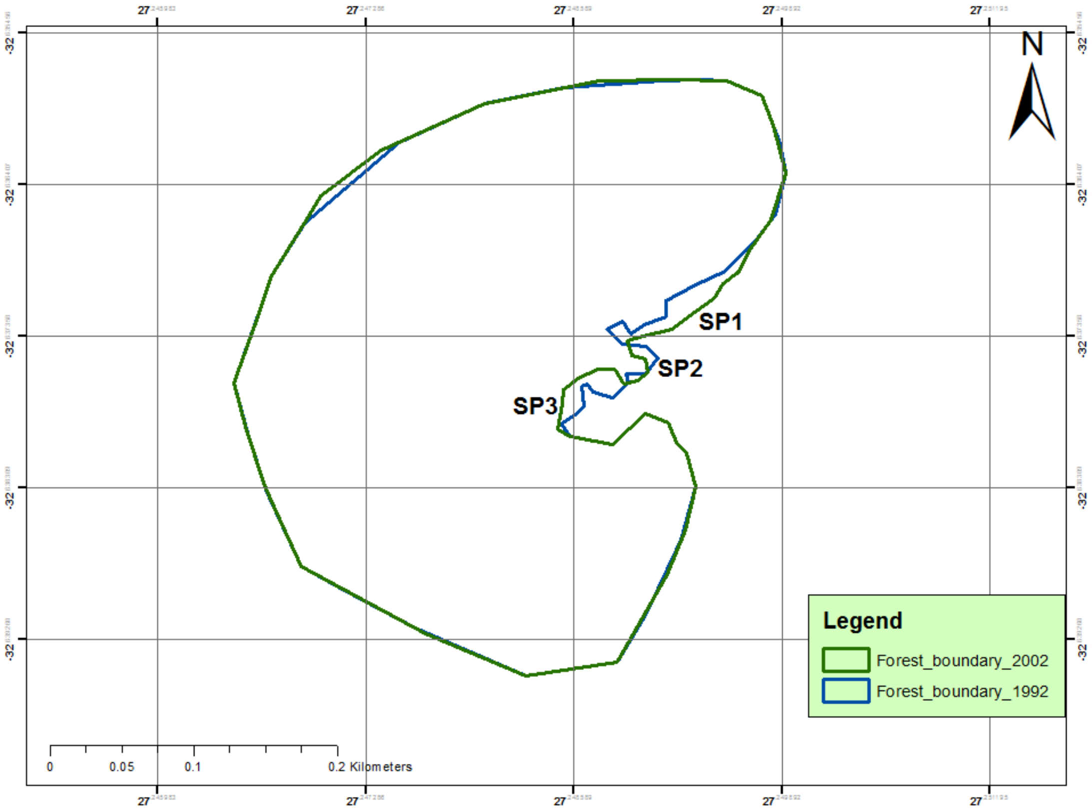

Figure 5h. Forest edge movement in research site 3 from 1992-2002

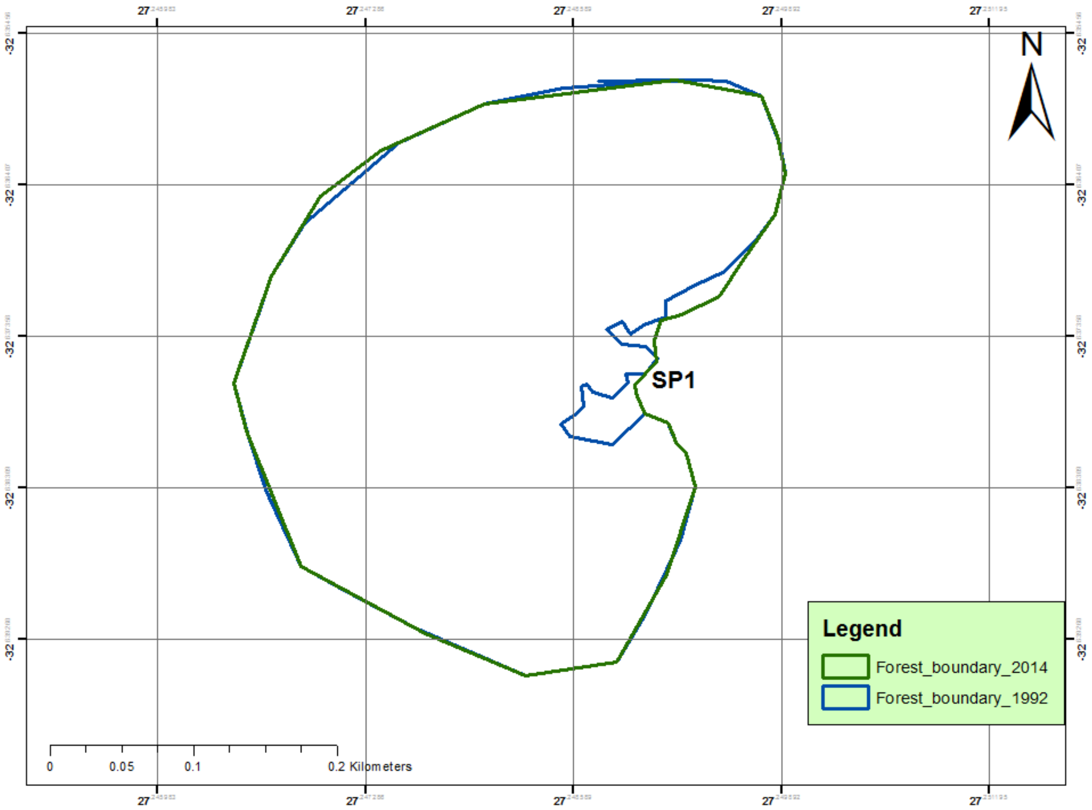

Figure 5i. Forest edge movement in research site 3 from 1992-2014

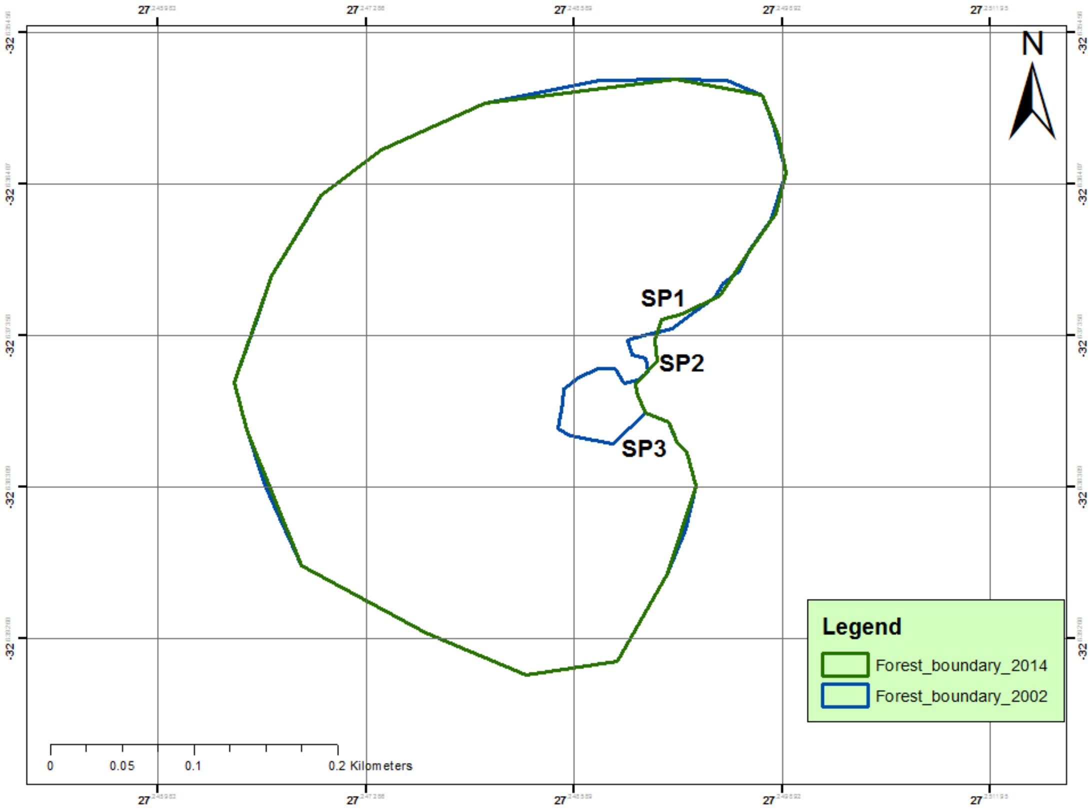

Figure 5j. Forest edge movement in research site 3 from 2002-2014

4.1.4 Forest edge movement at research site 4

Research site 4 showed erratic forest edge movement over time (Table 3). In 1975 to 1985 the site demonstrated positive forest edge movement. From 1975 to 2014, 1992 to 2014 and 2002 to 2014 of this study the site showed negative movement of the forest edge. From 1992 to 2002 the site showed positive forest edge movement with a distance of 79.2m and change in forest cover by 41 060.8m^2.

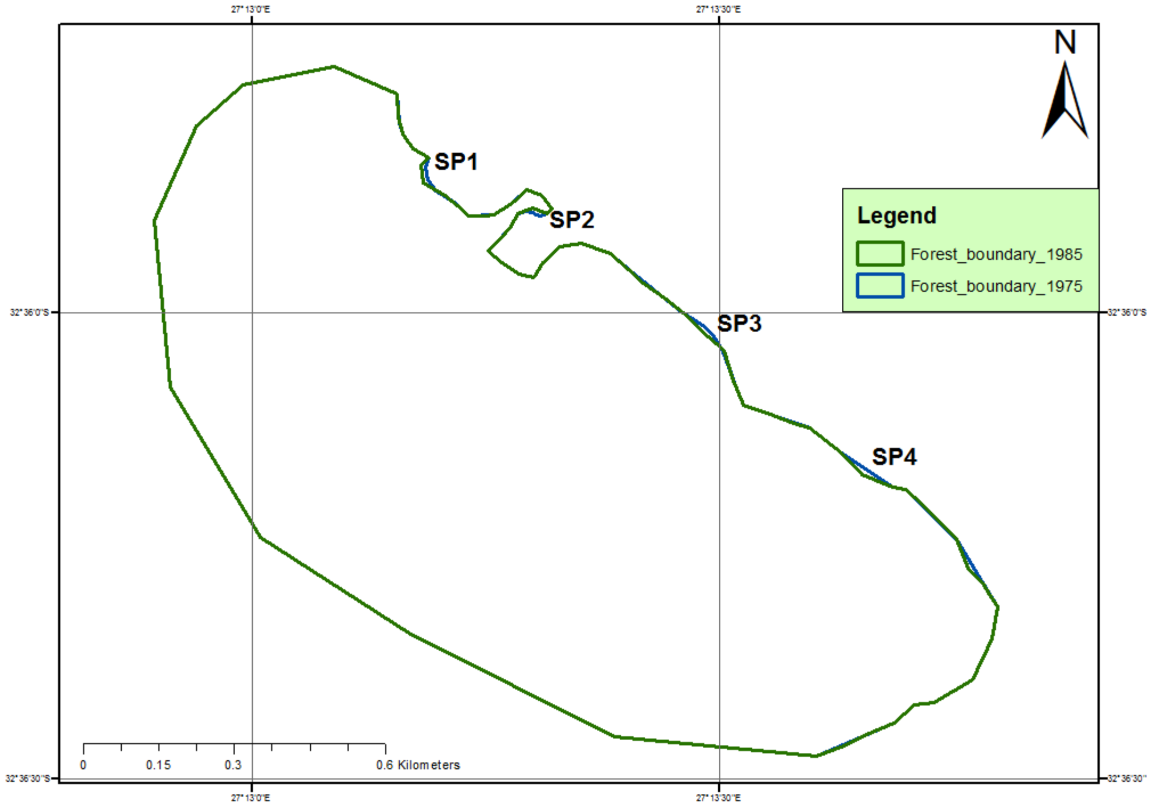

Figure 6a. Forest edge movement in research site 4 from 1975-1985

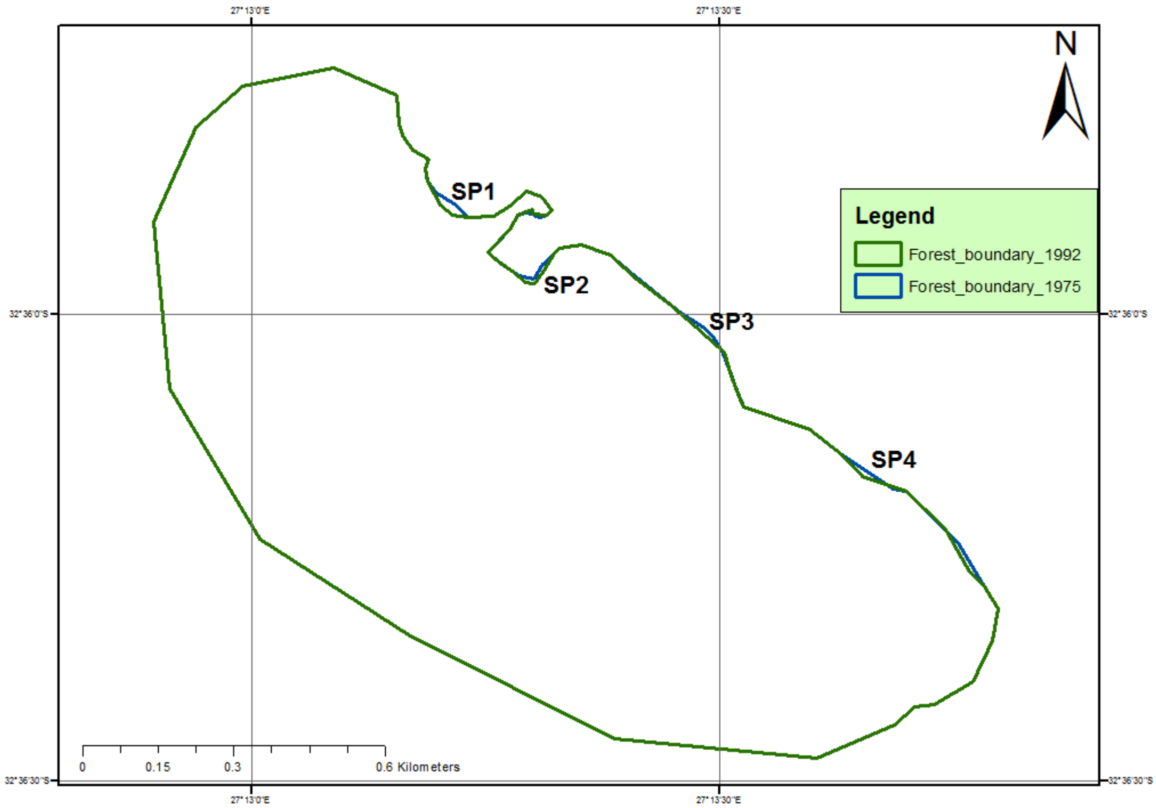

Figure 6b. Forest edge movement in research site 4 from 1975-1992

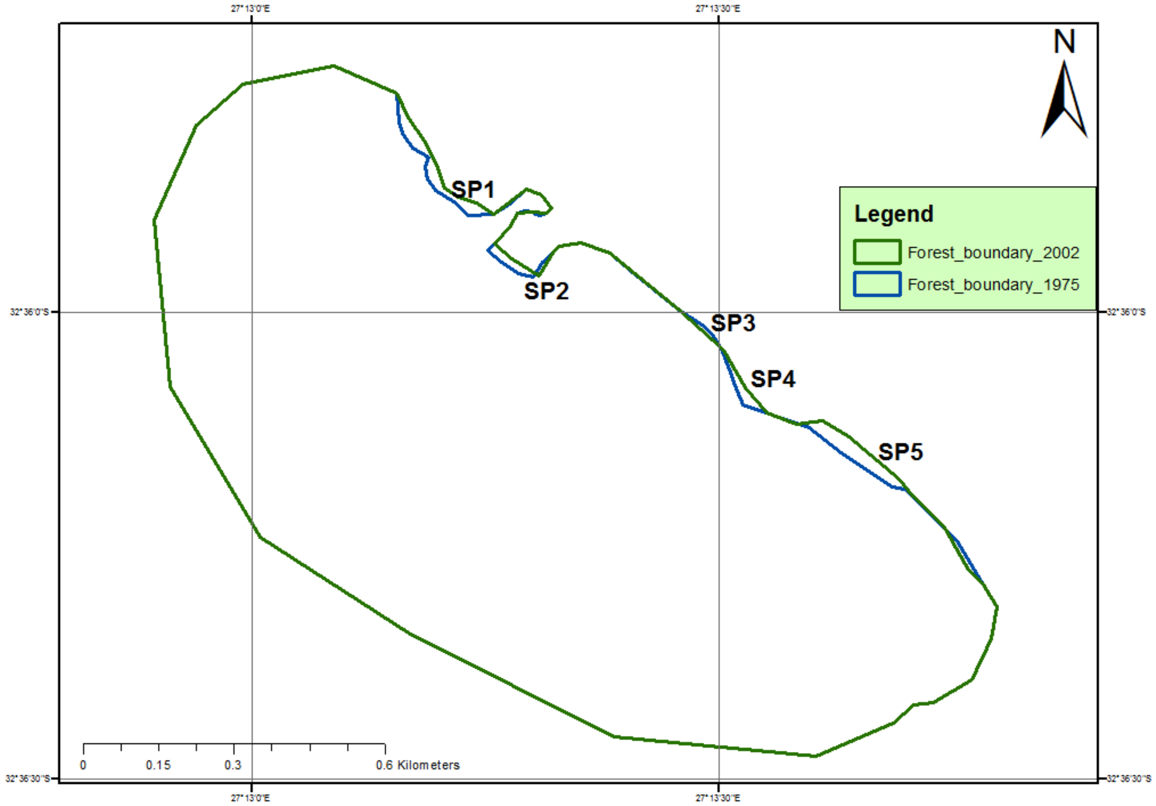

Figure 6c. Forest edge movement in research site 4 from 1975-2002

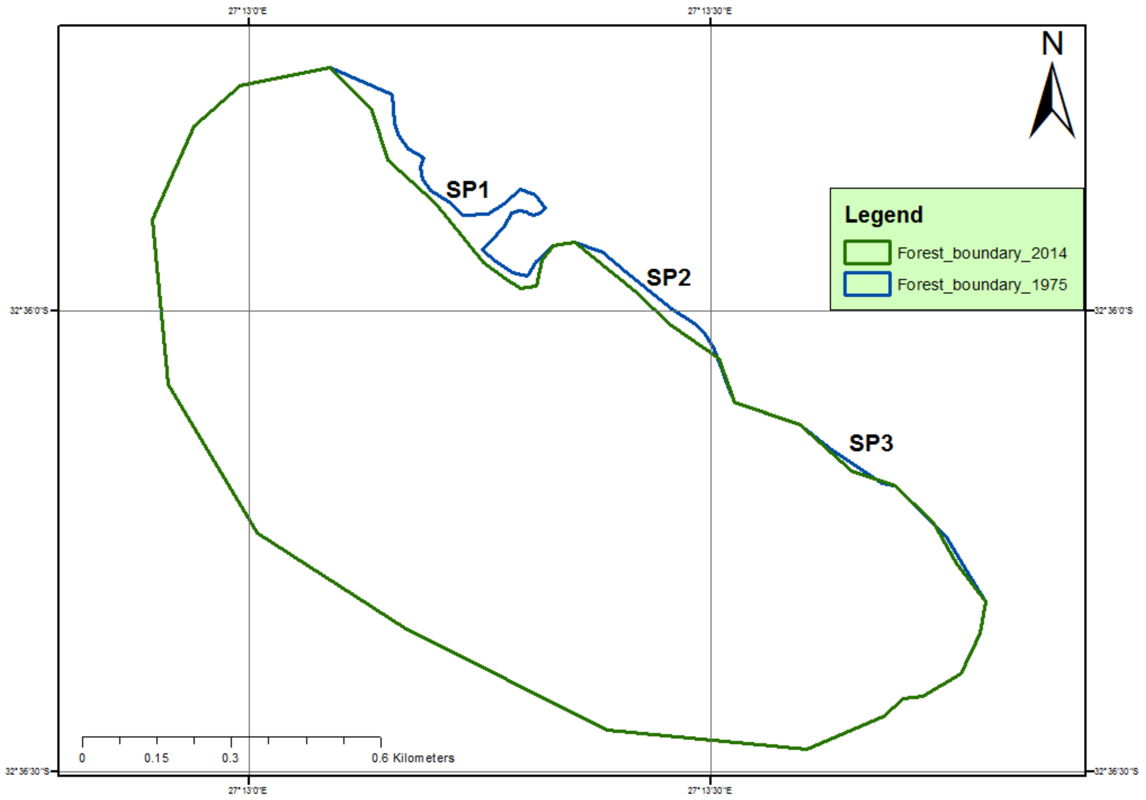

Figure 6d. Forest edge movement in research site 4 from 1975-2014

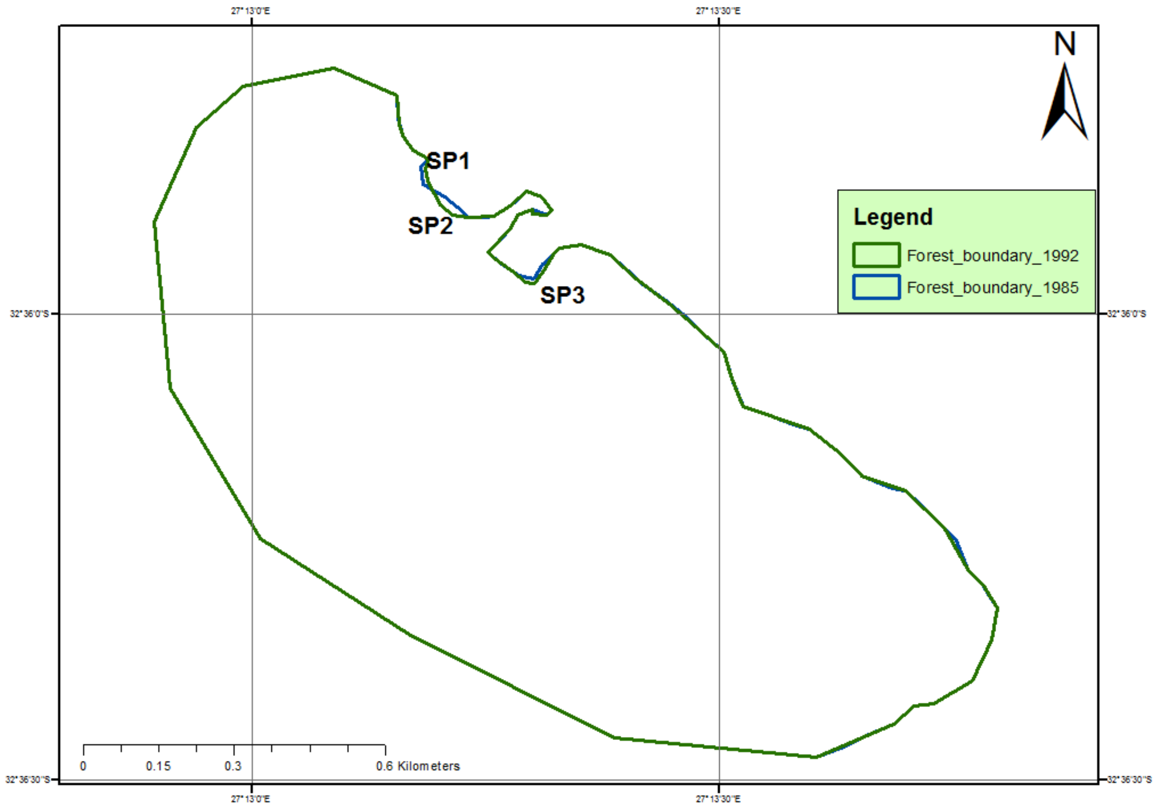

Figure 6e. Forest edge movement in research site 4 from 1985-1992

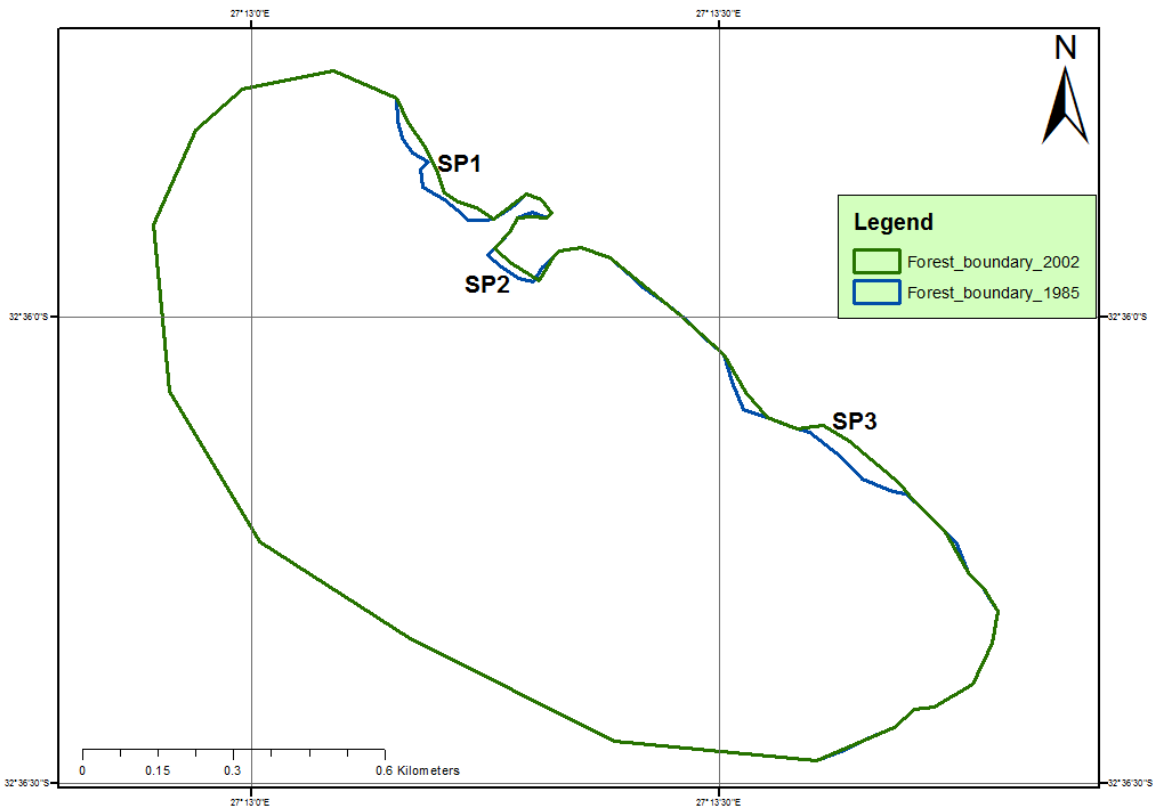

Figure 6f. Forest edge movement in research site 4 from 1985-2002

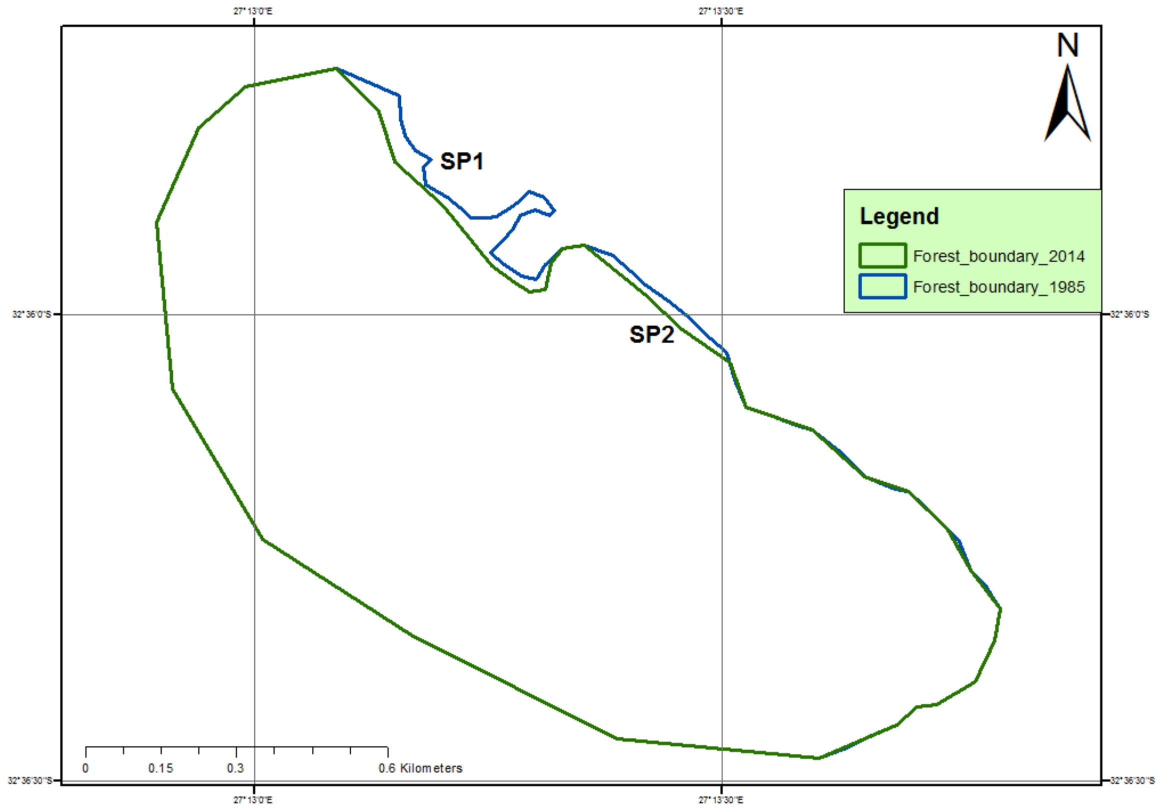

Figure 6g. Forest edge movement in research site 4 from 1985-2014

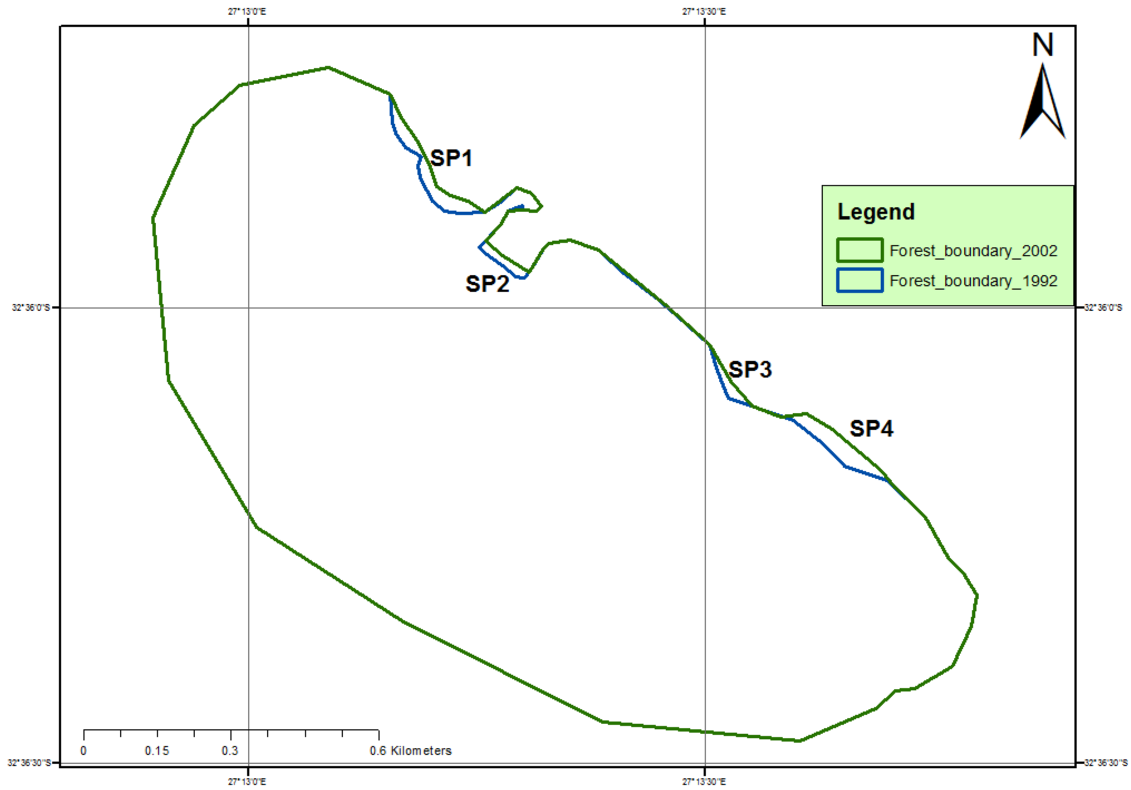

Figure 6h. Forest edge movement in research site 4 from 1992-2002

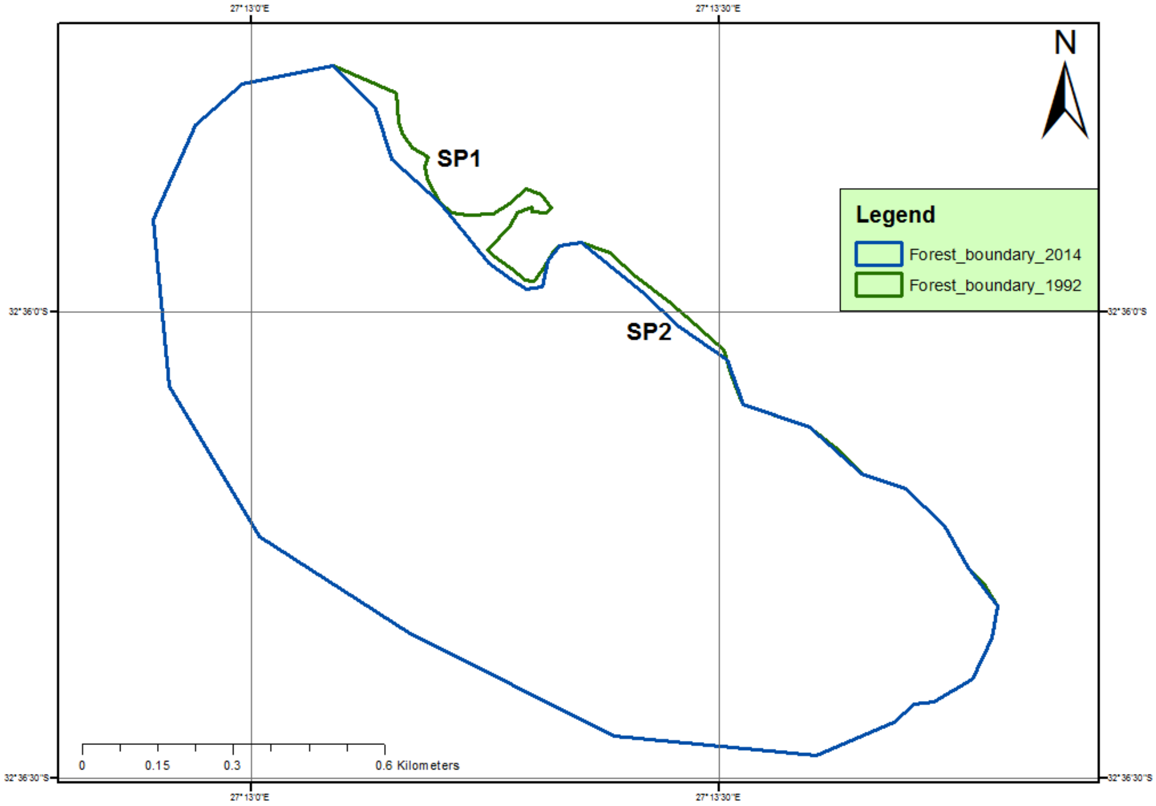

Figure 6i. Forest edge movement in research site 4 from 1992-2014

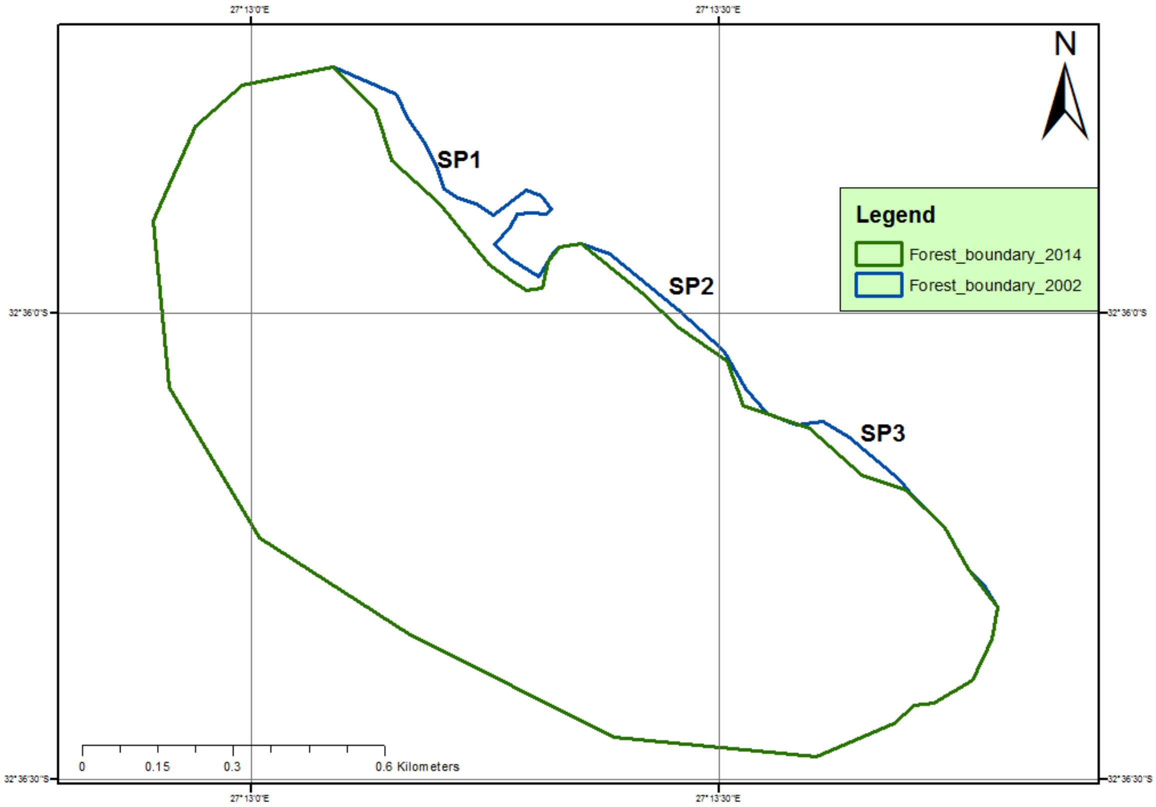

Figure 6j. Forest edge movement in research site 4 from 2002-2014

4.1.5 Forest edge movement at research site 5

At research site 5 there is only one year interval in the past from 1975 to 1985 that showed negative forest edge movement as demonstrated by SP3 in Figure 7a (Table 3). After 1985 the site showed a trend of positive forest edge movement (Table 3 and 4). This site exhibited positive movement of the forest edge in the SE aspect and a high magnitude of ecotone expansion (Figure 7a-j). There is a continuous movement of forest edge from 1975 to 1992, 1975 to 2002, 1975 to 2014, 1985 to 1992, 1985 to 2002, 1985 to 2014, 1992 to 2002, 1992 to 2014 and 2002 to 2014 year intervals as indicated by SP1,2,3 and 4.

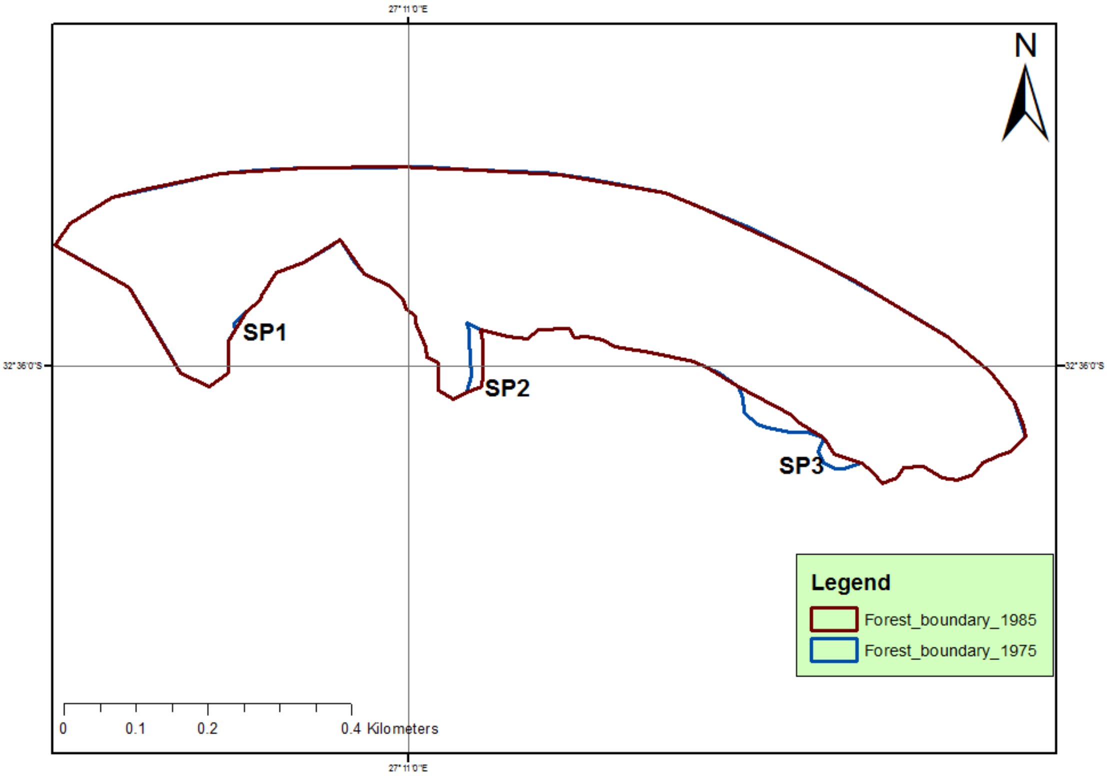

Figure 7a. Forest edge movement in research site 5 from 1975-1985

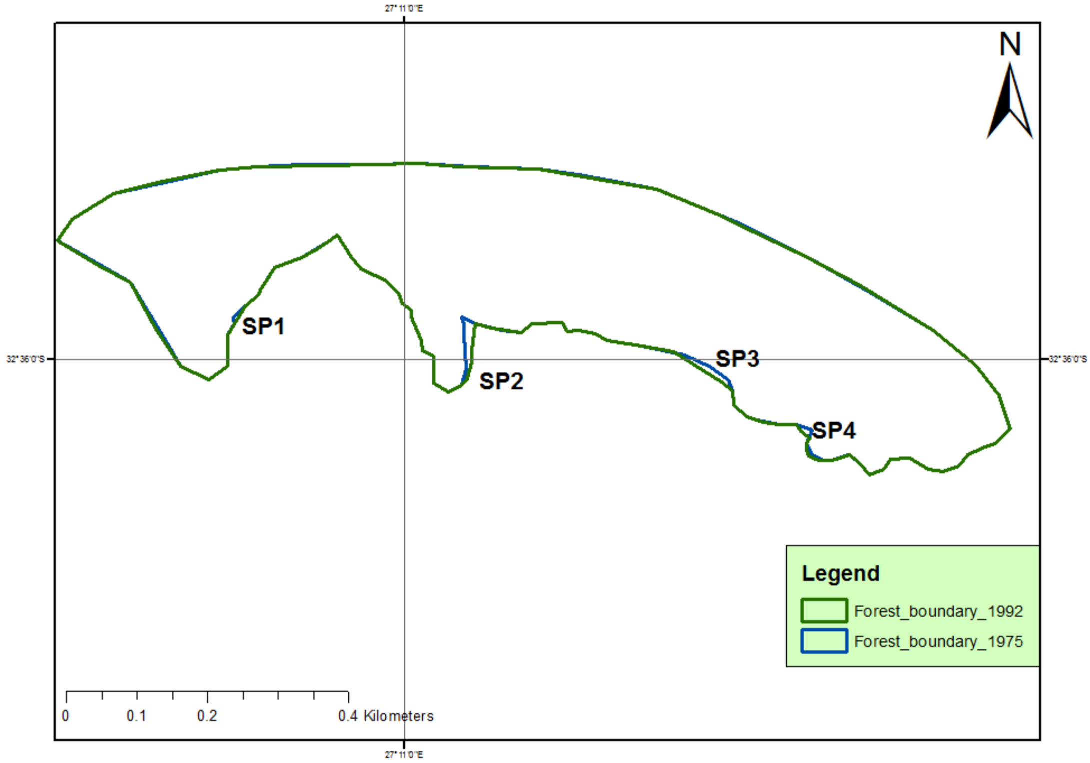

Figure 7b. Forest edge movement in research site 5 from 1975-1992

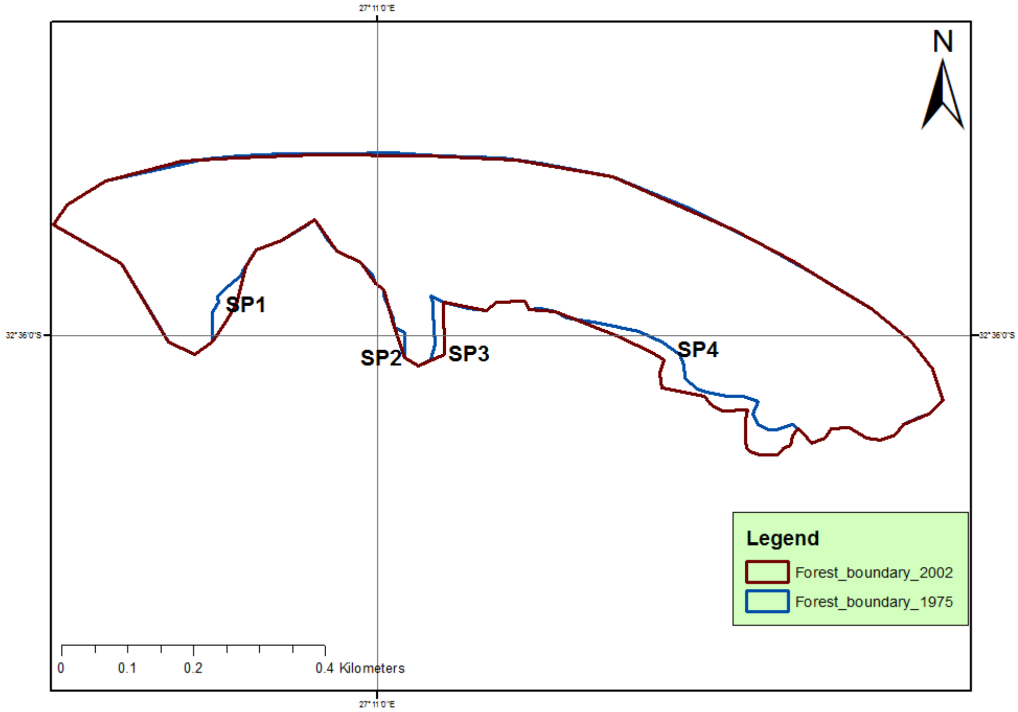

Figure 7c. Forest edge movement in research site 5 from 1975-2002

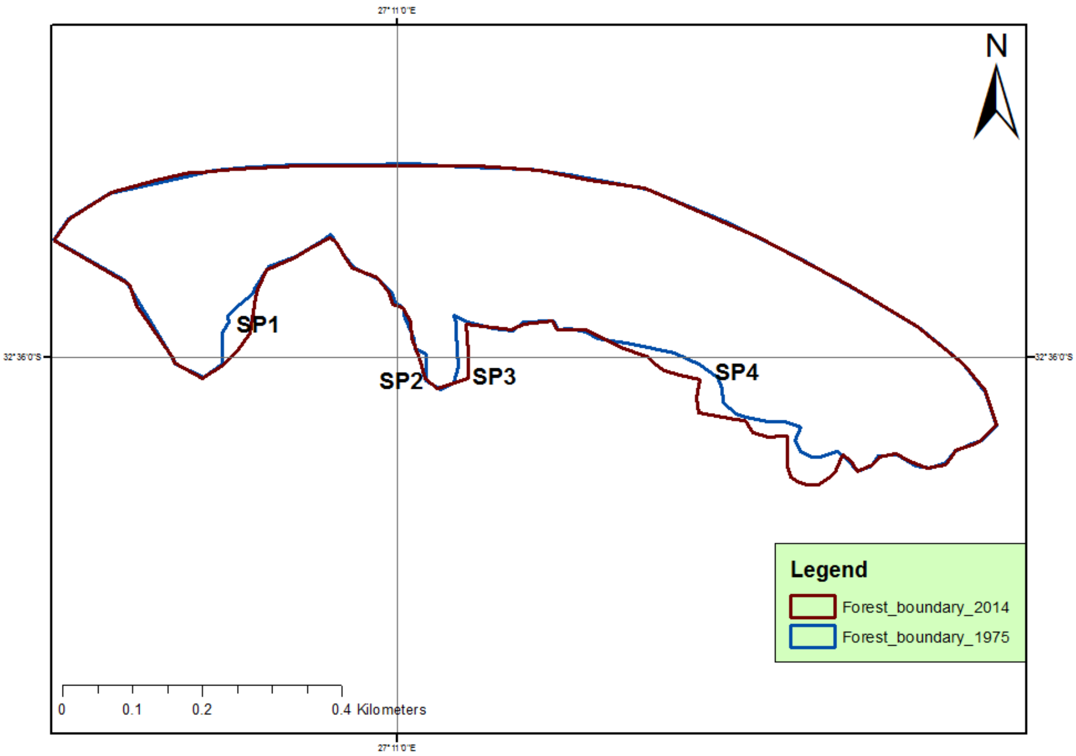

Figure 7d. Forest edge movement in research site 5 from 1975-2014

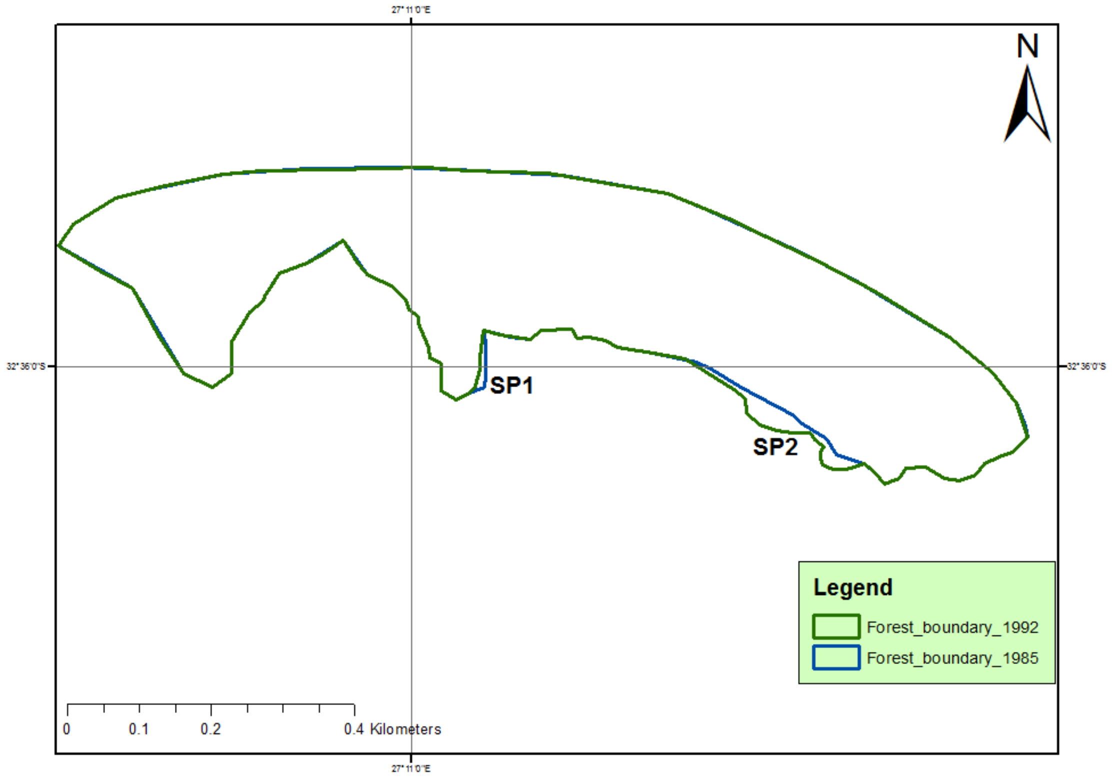

Figure 7e. Forest edge movement in research site 5 from 1985-1992

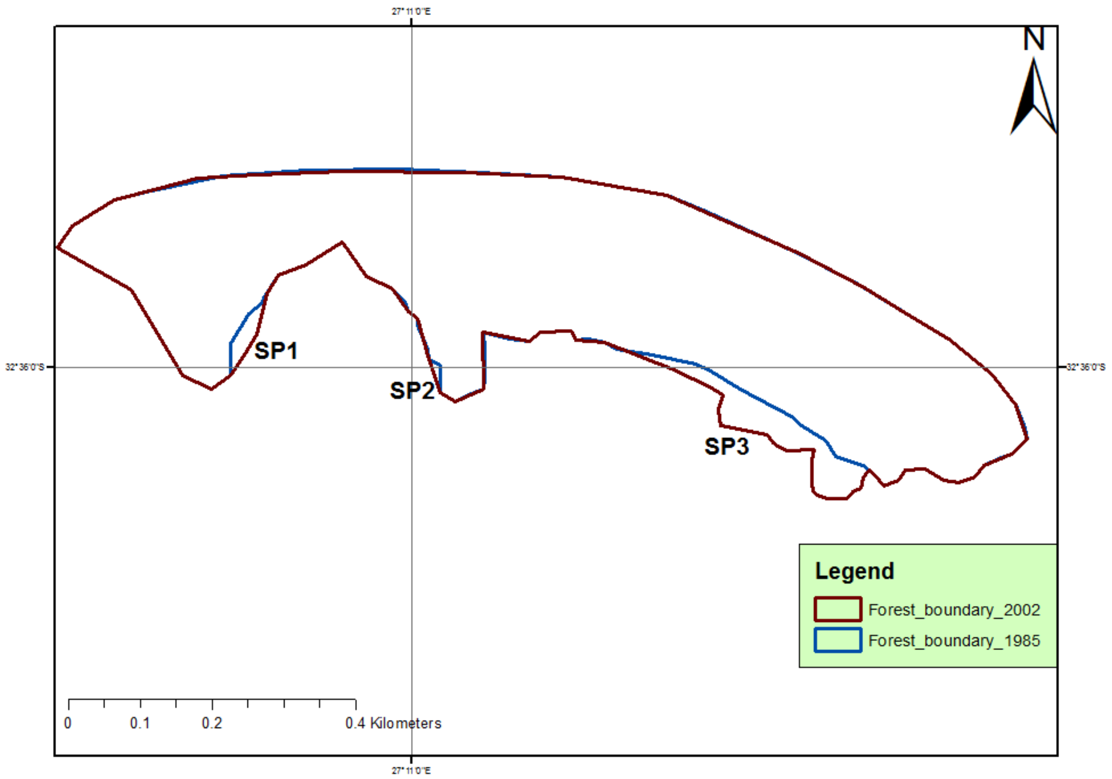

Figure 7f. Forest edge movement in research site 5 from 1985-2002

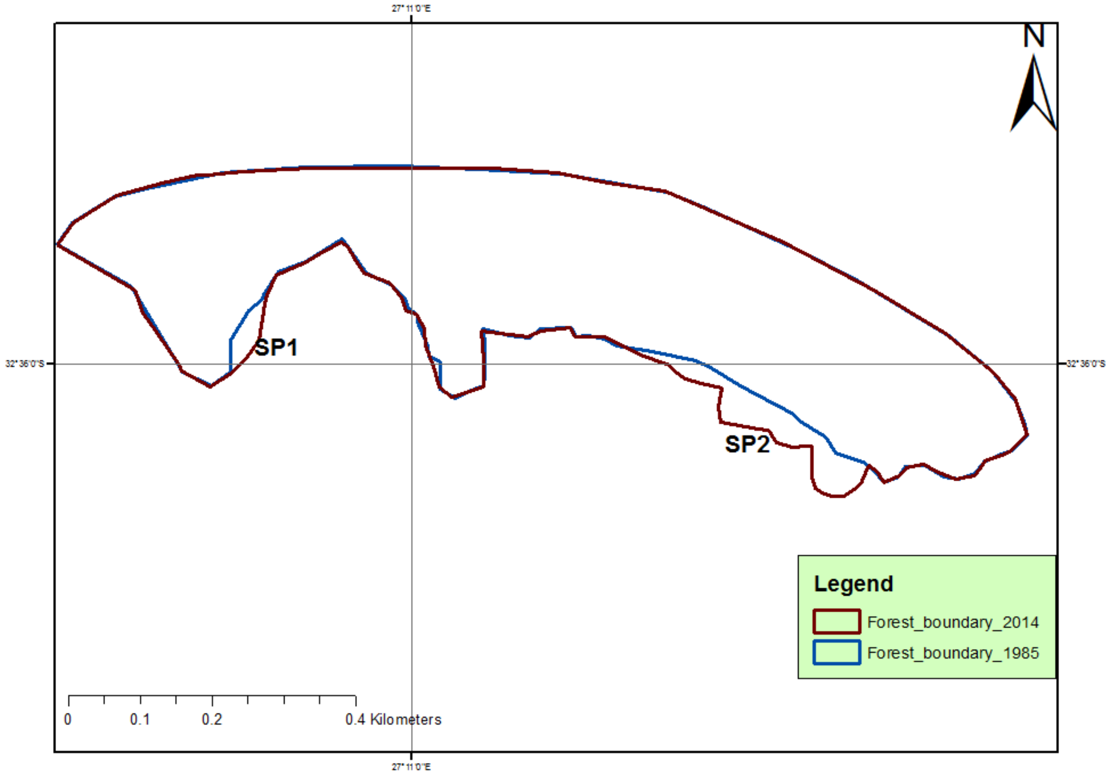

Figure 7g. Forest edge movement in research site 5 from 1985-2014

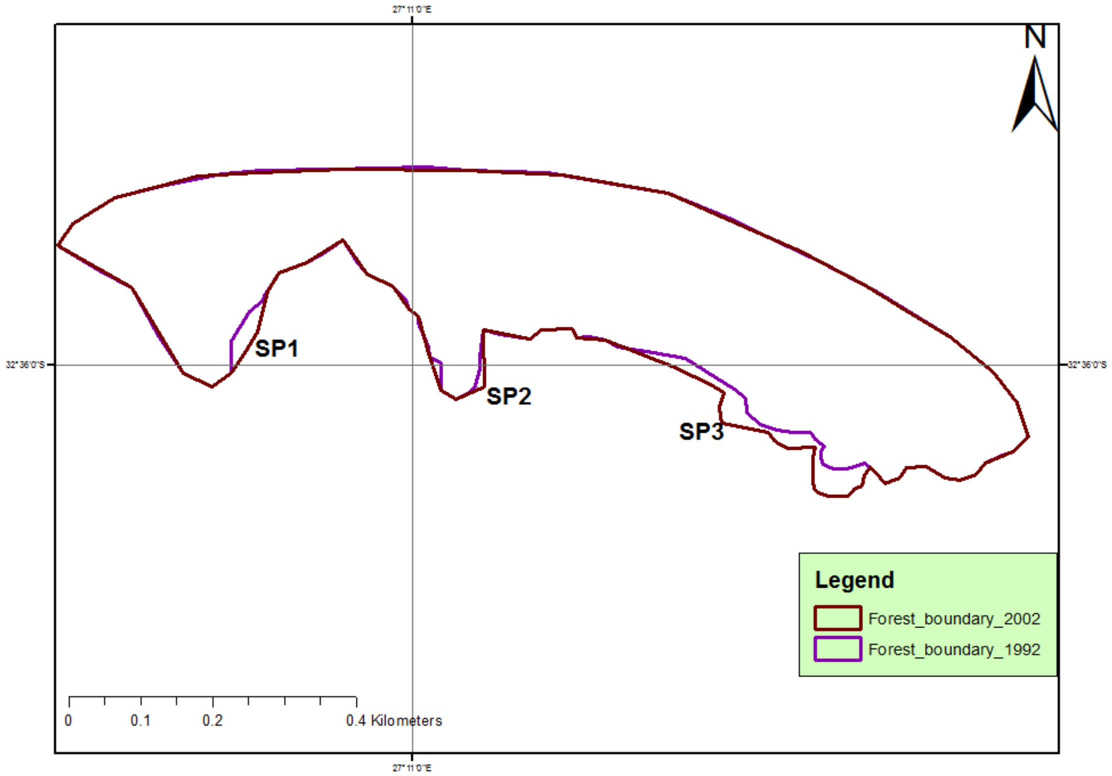

Figure 7h. Forest edge movement in research site 5 from 1992-2002

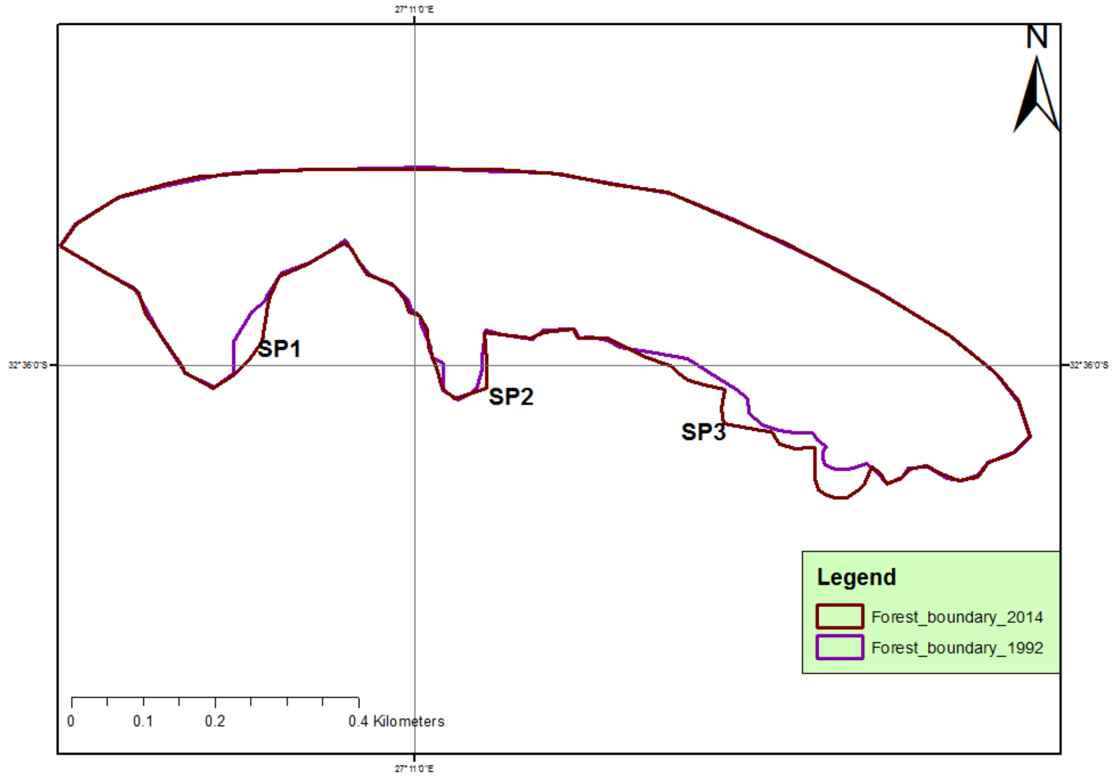

Figure 7i. Forest edge movement in research site 5 from 1992-2014

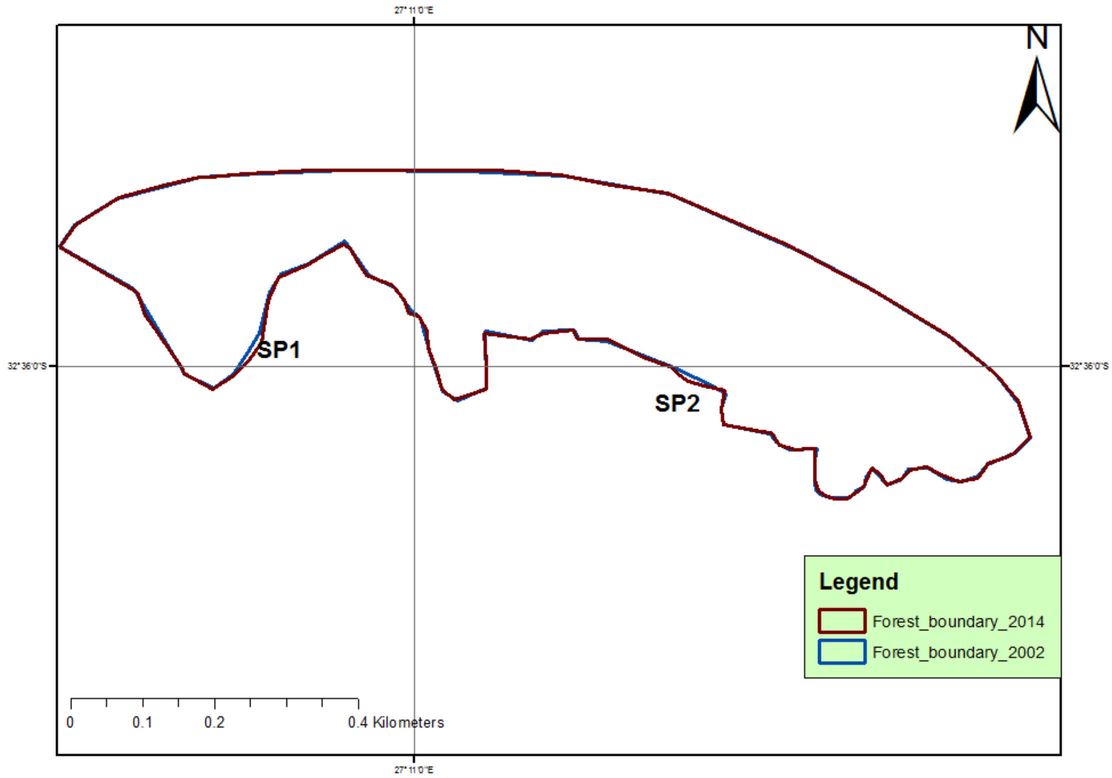

Figure 7j. Forest edge movement in research site 5 from 2002-2014

4.1.6 Forest edge movement at research site 6

At research site 6 there is a trend of forest edge movement from 1975 to 1985 which is the early years of the study until the current year intervals 2002 to 2014. This site demonstrated high positive movement of the forest edge in the SW and SE aspect of the forest patch, with the SE aspect showing a high degree of positive forest edge movement and forest cover change over time (Table 3 and 4). From 1975-2014 the results show overall change of forest ecotone area as 39 456m^2 further validating the high degree of forest cover change in research site 6.

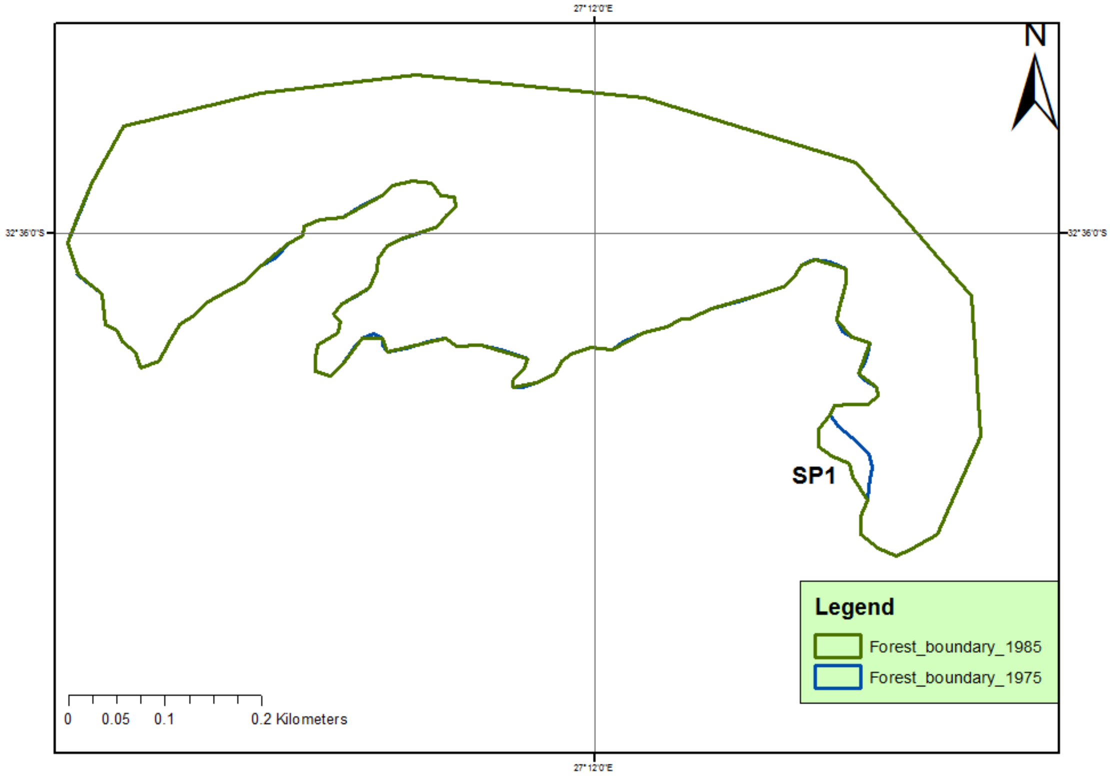

Figure 8a. Forest edge movement in research site 6 from 1975-1985

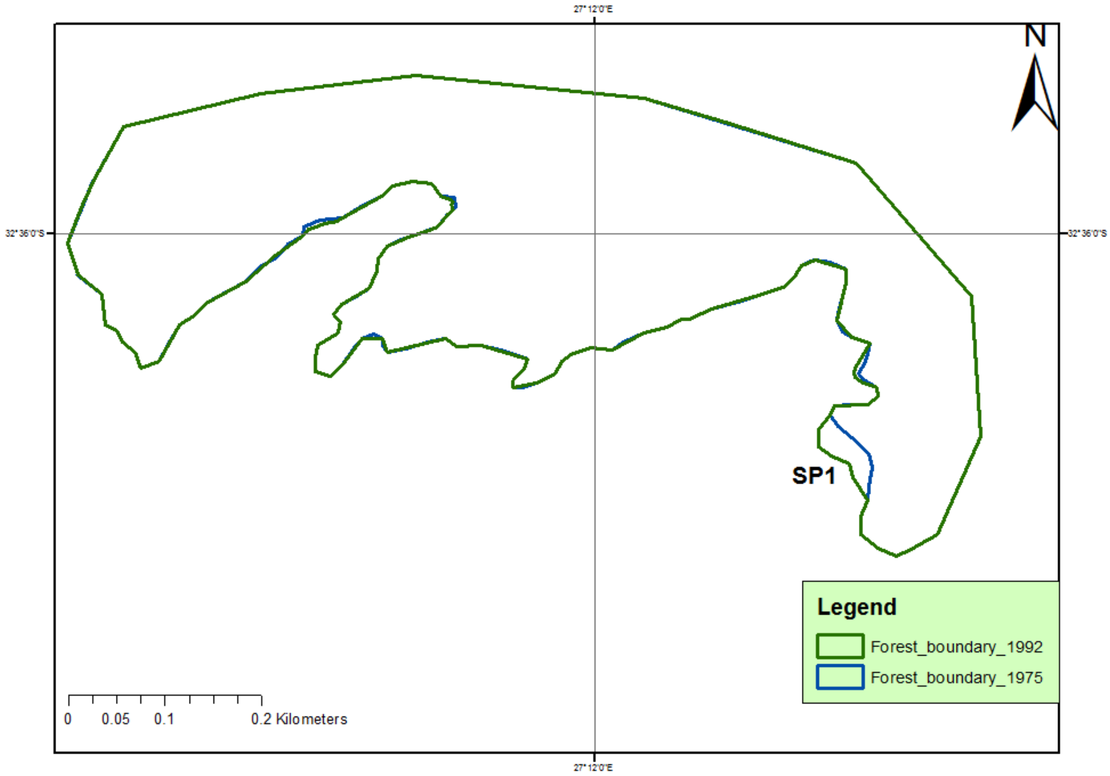

Figure 8b. Forest edge movement in research site 6 from 1975-1992

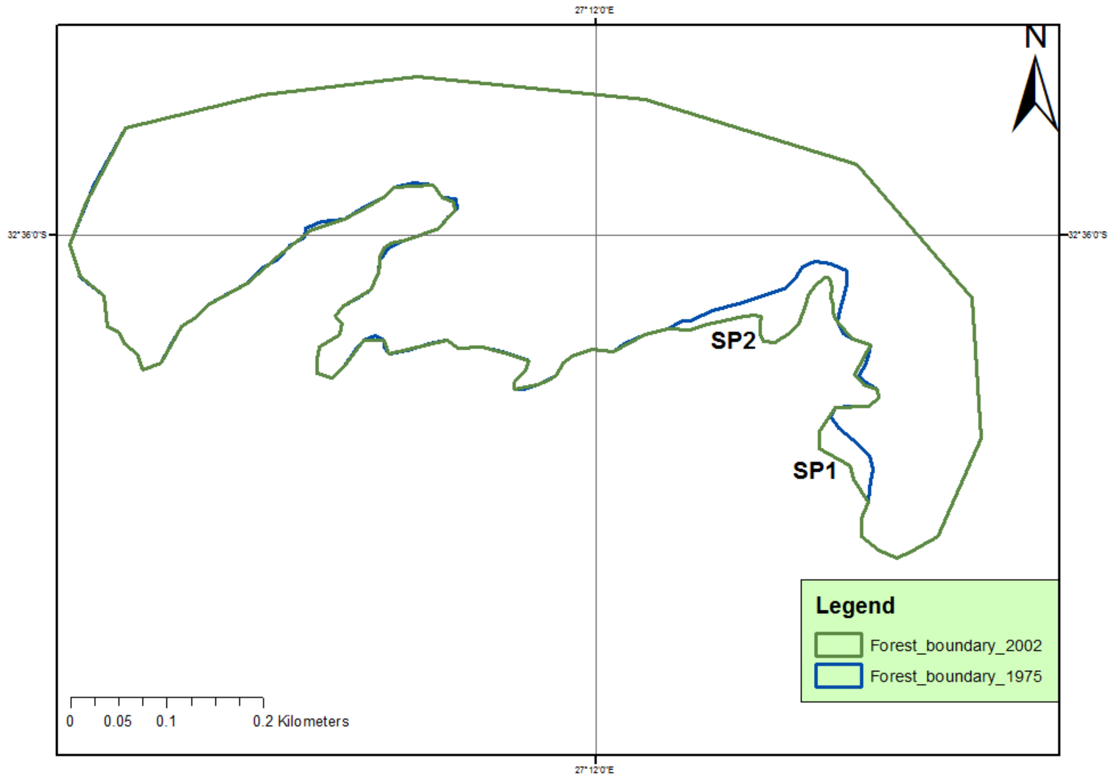

Figure 8c. Forest edge movement in research site 6 from 1975-2002

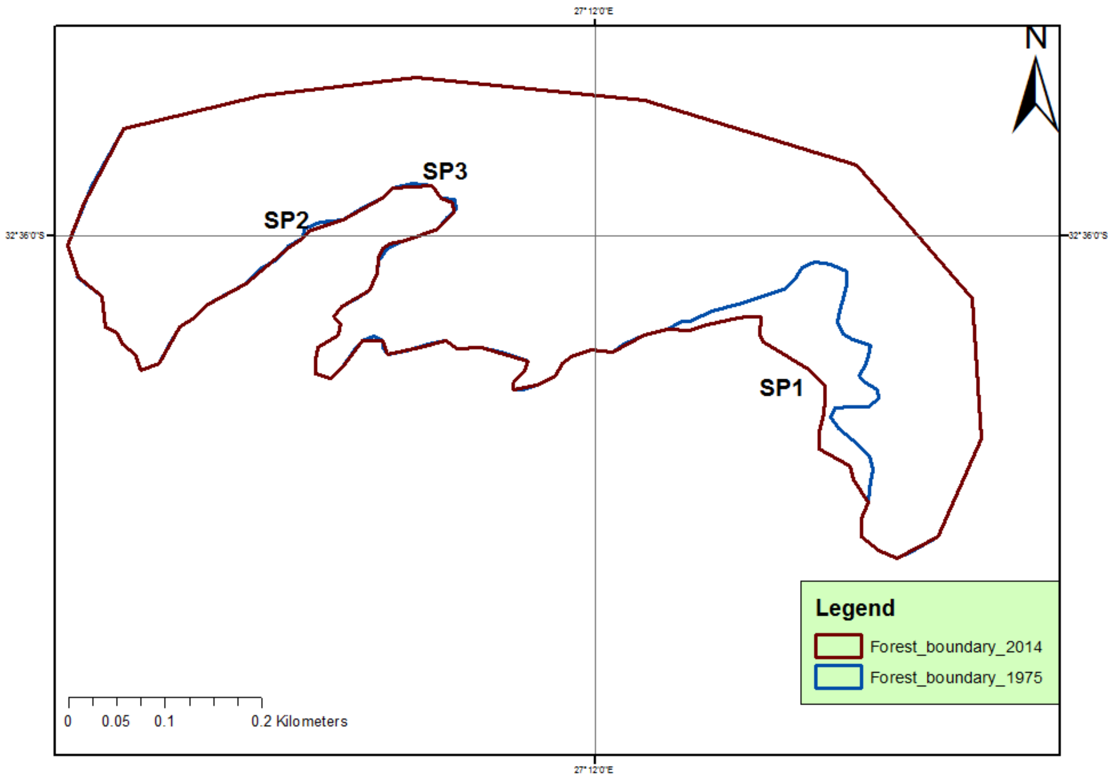

Figure 8d. Forest edge movement in research site 6 from 1975-2014

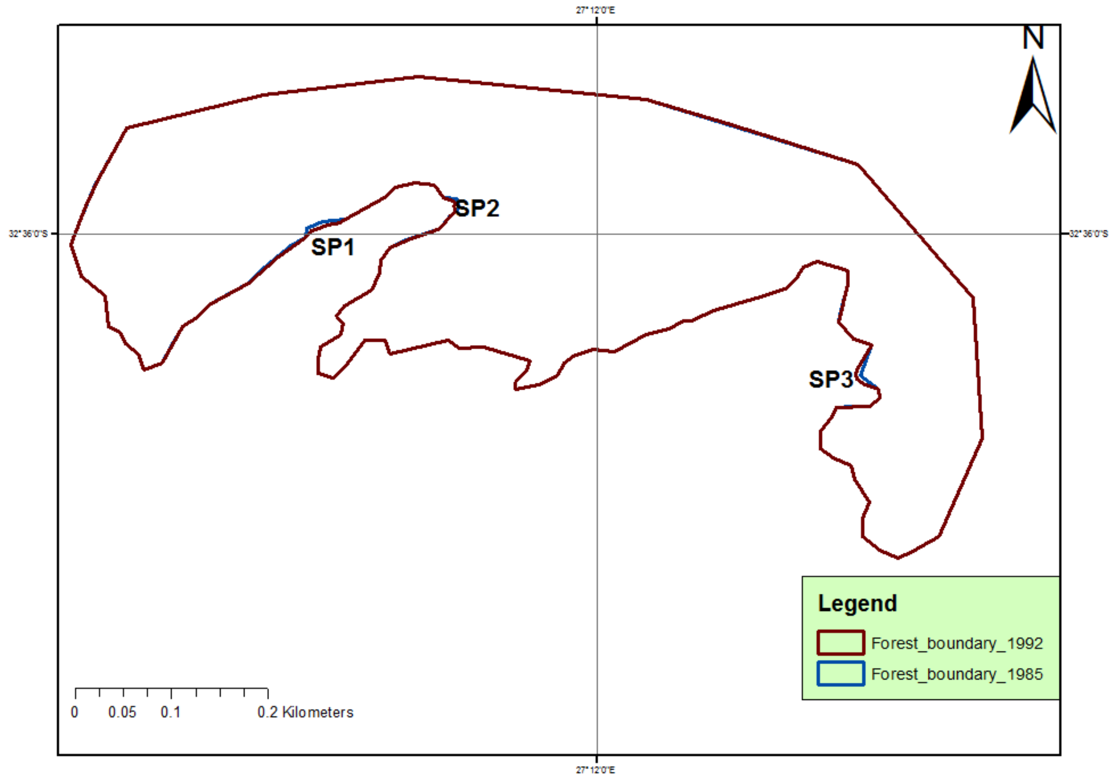

Figure 8e. Forest edge movement in research site 6 from 1985-1992

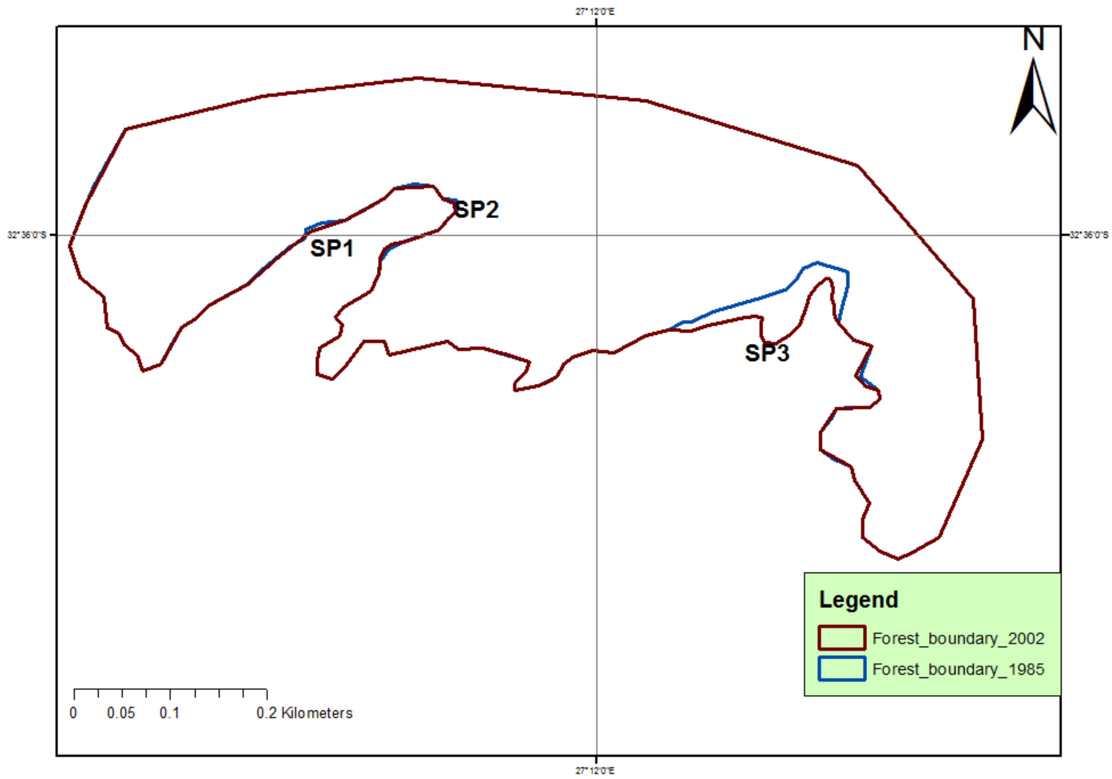

Figure 8f. Forest edge movement in research site 6 from 1985-2002

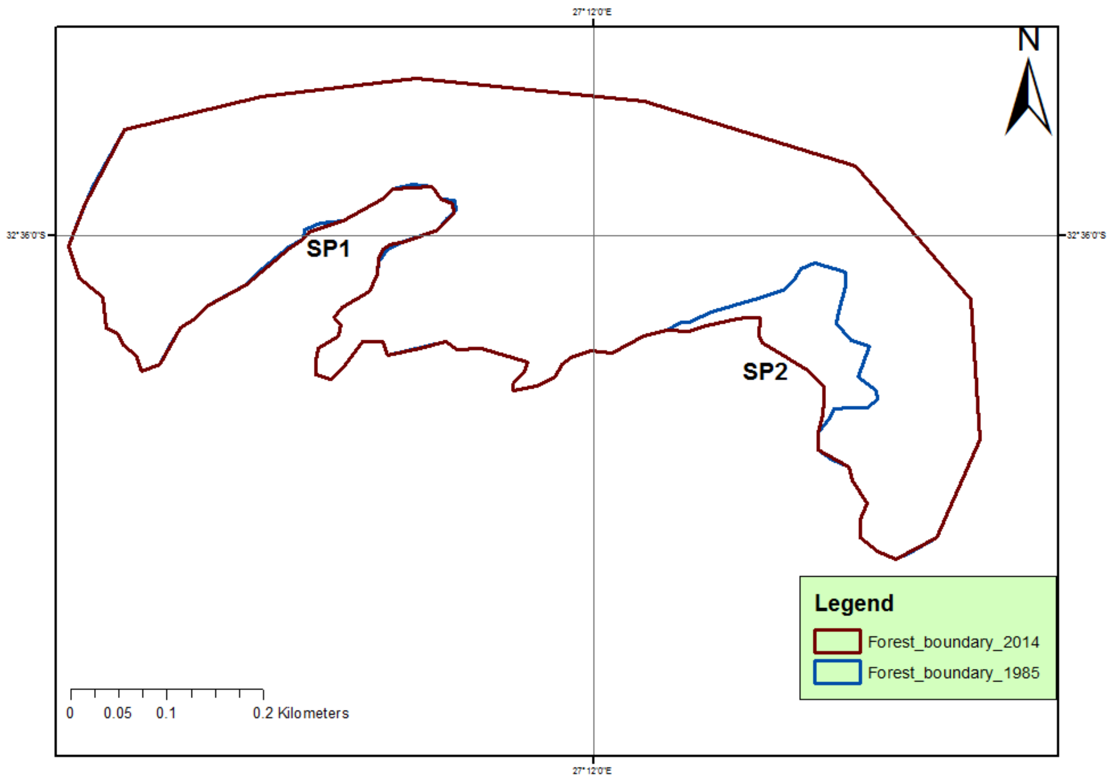

Figure 8g. Forest edge movement in research site 6 from 1985-2014

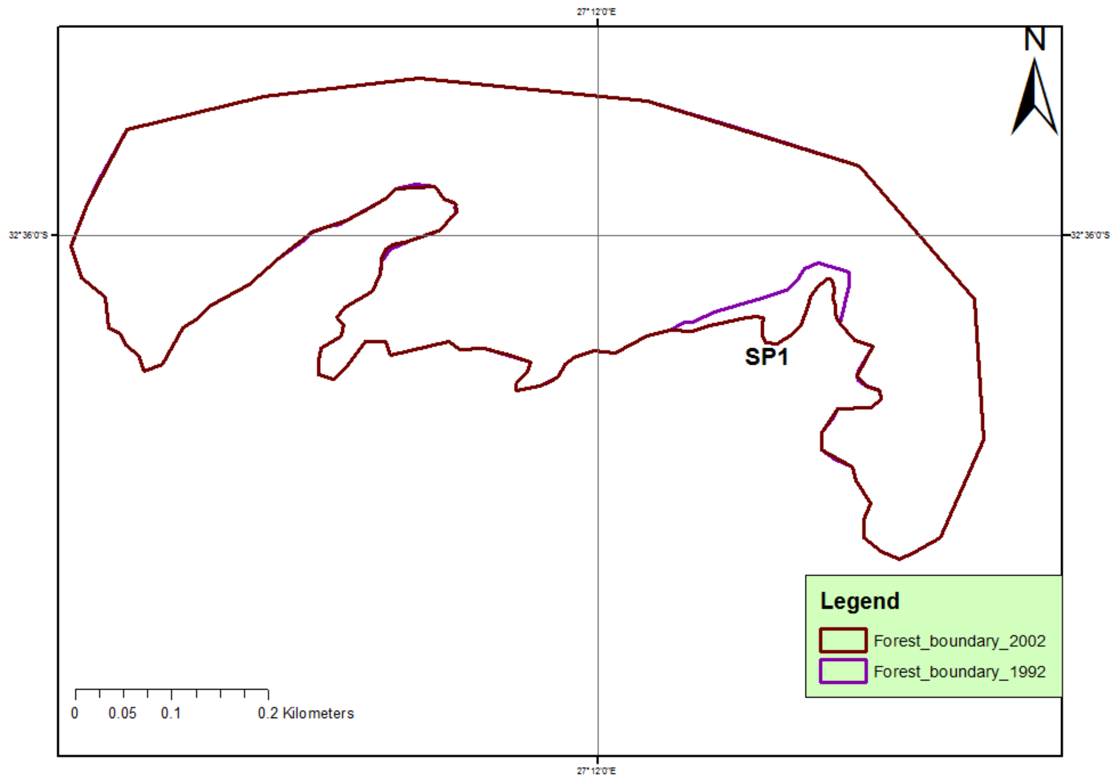

Figure 8h. Forest edge movement in research site 6 from 1992-2002

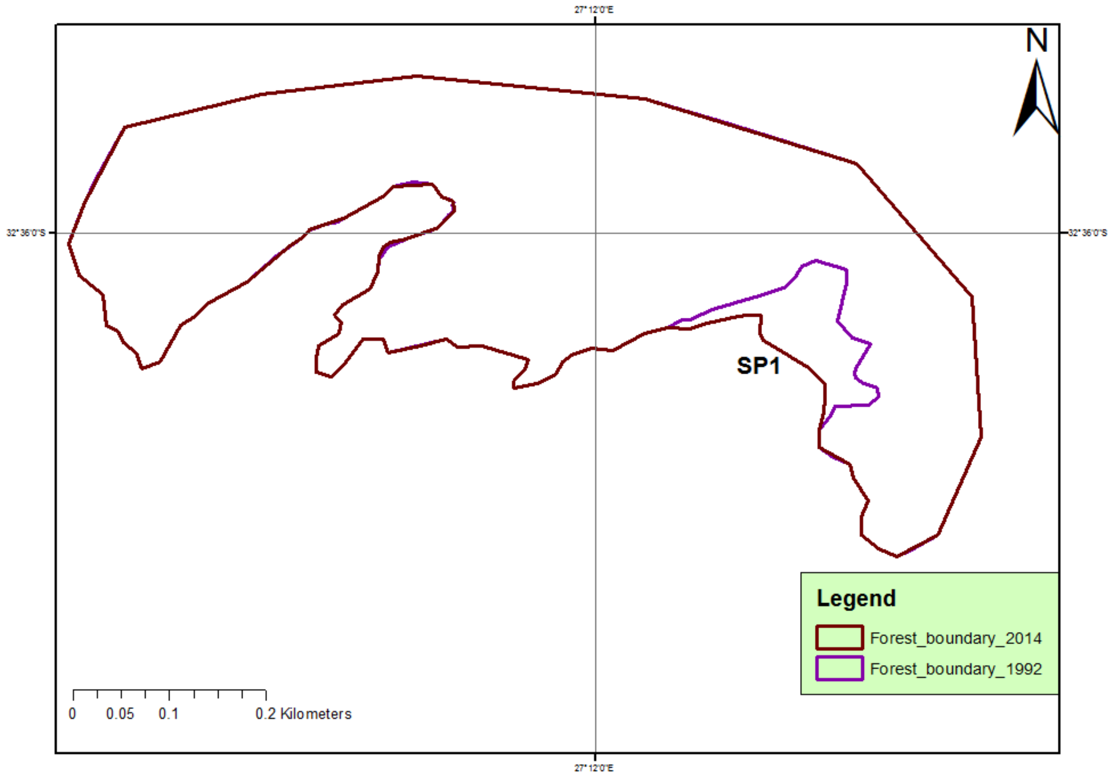

Figure 8i. Forest edge movement in research site 6 from 1992-2014

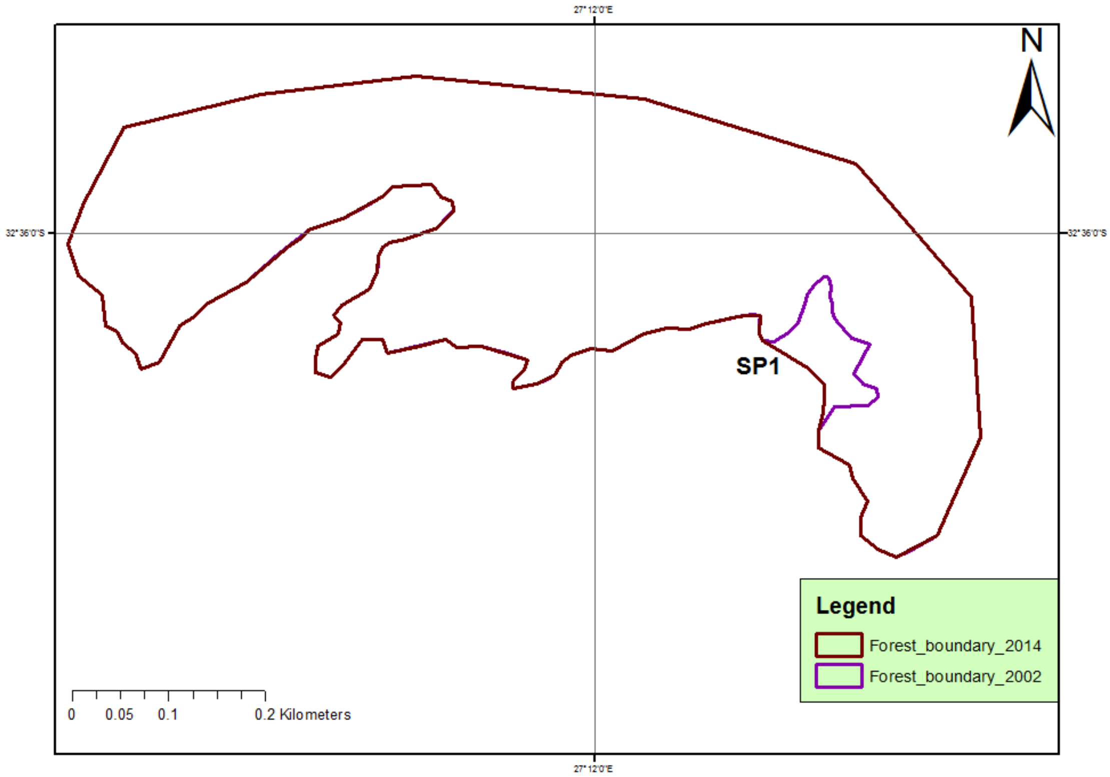

Figure 8j. Forest edge movement in research site 6 from 2002-2014

4.2 The relationship between plant species density, species richness and forest edge movement.

From 1975 to 2014, the forest edge at research site 3 moved by an average distance of 45.7m and at research site 5 by an average of 10.6m respectively (Table 1). The forest edge movements were positive at both sites. Based on Pearson's statistical model the analysis of plant density data and average distance of forest edge movement shows no correlation between forest edge movement at research site 3 and 5. At research site 3 *A latifolius* has a high density in the interior of the forest with 10 individual stems per quadrat (50m² in size) from 0-10m and 1 individual stem at a distance of 10.1-20m and it was also found in the exterior of the forest with its density declining to 2 and 5 individual stems per quadrat in a distance of 20-30m and 30.1-40m respectively.

A latifolius had a negative relationship with forest edge movement (P value=-.704 and S value = 0.05) at research site 3. *A facultus* had low density with 1 individual stem per quadrat in a distance of 20.1-30m and between 50.1-60m and it showed a negative relationship with forest edge movement (P value=-.174 and S value=0.6). *D whyteana* showed low density with 2 individual stems identified at a distance of 60.1-80m in the forest ecotone and this plant species had a poor relationship with forest edge movement at research site 3 (P value =.348 and S value = 324). *H lucida* had 1 individual stem per quadrat at distance of 60.1-70m and 70.1-80m of the belt transect and it showed a poor relationship with forest edge movement (P value=.174 and .631). *R melanophloes* had low density with 1 and 2 individual stems found at a distance of 20.1-30m and 40.1-50m and it had a negative relationship with forest edge movement (P value= -.190 and S value=.598). *S chirindensis* showed low density in the exterior of the forest with 1 individual stem identified growing at a distance of 20.1-30m and at 60.1-70m respectively and the plant had a negative relationship with forest edge movement. *Z dvyii* also had low density with 1 individual stem per quadrat identified at a distance of 80.1-90m showing poor relationship with forest edge movement (P value=.406 and S value=.244) (Table 3). At research site 5 *A latifolius* had a density of 5 individual stems per quadrat while *A facultus* had a density of 1 individual stem per quadrat only in the interior of the forest and both of these plant species showed negative relationship with forest edge movement (P value=-.522 and S value=.122).

B ilicifolia had low density of 1 individual stem per quadrat at a distance of 20.1-30m in the forest ecotone and it had a negative relationship with forest edge movement (P value=-.290 and S value=.416). *C aurea* had low density of 1 individual stem per quadrat at a distance of 60.1-70m and it also showed negative relationship with forest edge movement (P value=-.522 and S value=.122). *C bispinosa*, *C inerme* and *C mundiana* had negative relationship with forest edge movement and they share the same P value (P value=-.522 and S =.122). *D whyteana* had high density in the interior of the forest with 13 and 2 individual stems from 0-10m and 10.1-20m but it had negative relationship with forest edge movement (P value=-.588 and S=.074). *M heterophylla* had low density with 1 individual stem per quadrat found in the exterior of the forest at 60.1-70m with poor relationship between forest edge movement (P value=.174 and S value=631).

R prenoides had density of 1 individual stem per quadrat in the interior of the forest at 0-10m and in the exterior with 1 individual stem identified at a distance of 20.1-30m and from 30.1-40m, this plant species had negative relationship with forest edge movement (P value=-.426 and S value =.219). *S chirindensis* is only found at a distance of 50.1-60m this plant showed negative relationship with forest edge movement (P =-.426 and S value=.219). *V lanceolata* had low density of 1 individual stem within the forest border with negative relationship between forest edge movement (P value =-.522 and S value =.122) (Table 5).

Table 5. Species density/unit area at research site 3 and 5

Site 3	Density									
	0-10 m	10.1-20m	20.1-30m	30.1-40m	40.1-50m	50.1-60m	60.1-70m	70.1-80m	80.1-90m	90.1-100m
Afrocarpus latifolius	10	1	2	5	2	0	0	0	0	0
Afrocarpus facultus	0	0	1	0	0	1	0	0	0	0
Diasporus whyteana	0	0	0	0	0	0	1	1	0	0
Halleria lucida	0	0	0	0	0	1	1	0	0	0
Rapanea melanophloes	0	0	1	0	2	0	0	0	0	0
Searsia chirindensis	0	0	1	0	0	0	1	0	0	0
Zanthoxylum devyii	0	0	0	0	0	0	0	0	1	0
Site 5										
Afrocarpus latifolius	5	0	0	0	0	0	0	0	0	0
Afrocarpus facultus	1	0	0	0	0	0	0	0	0	0
Brachyleana ilicifolia	0	0	1	0	0	0	0	0	0	0
Calpurnia aurea	0	0	0	0	0	0	1	0	0	0
Carrisa bispinosa	5	0	0	0	0	0	0	0	0	0
Canthium inerme	5	0	0	0	0	0	0	0	0	0
Canthium mundiana	3	0	0	0	0	0	0	0	0	0
Diasporus whyteana	13	2	0	0	0	0	0	0	0	0
Maytenus heterophylla	0	0	0	0	0	0	1	0	0	0
Rhumnus prenoides	1	0	1	1	0	0	0	1	0	0
Scolopia	1	0	0	0	0	0	0	0	0	0

mundi										
Searsia chirindensis	0	0	0	0	0	1	0	0	0	0
Vepris lanceolata	1	0	0	0	0	0	0	0	0	0

4.2.1 Plant species richness at research site 3 and 5

Species richness changes with distance from the interior of the forest to the exterior (Table 6). There was also a decline of species richness from the forest border to the exterior of the forest at research site 3 and 5 (Figure 9 and 10). There was a negative relationship (P value=-.910 and S=0.01) between species richness and distance of forest edge movement at research sites 3 and 5.

Table 6. Species richness of research site 3 and 5

Distance (m)	**Species richness**	
	Site 3	**Site 5**
0-10	10	7
10.1-20	8	1
20.1-30	4	0 (no species encountered)
30.1-40	4	3
40.1-50	4	4
50.1-60	2	5
60.1-70	3	3
70.1-80	1	4
80.1-90	1	0
90.1-100	0	0
Total number of individuals sampled (n)	n=83	n=50

Species richness=number of different species in a quadrat

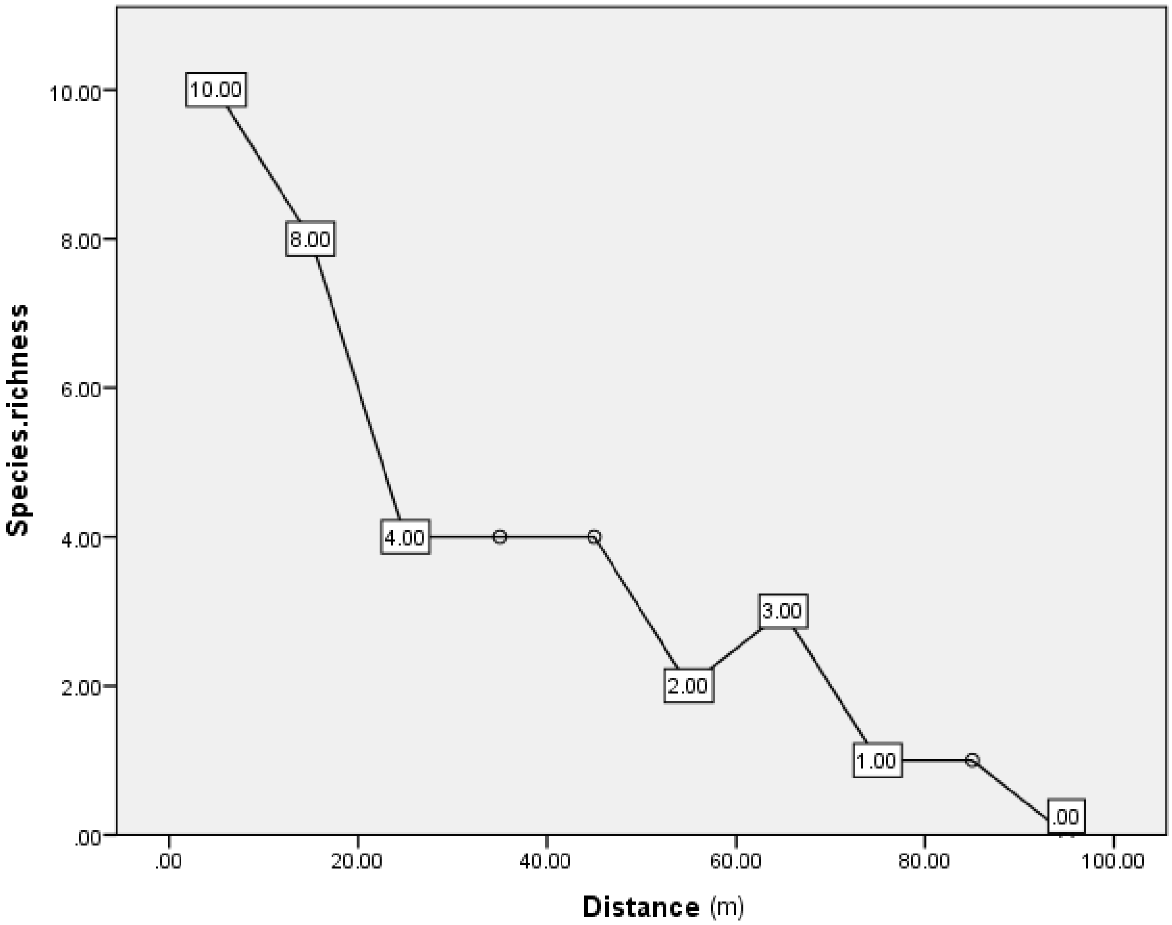

Figure 9. Trend in species richness at research site 3

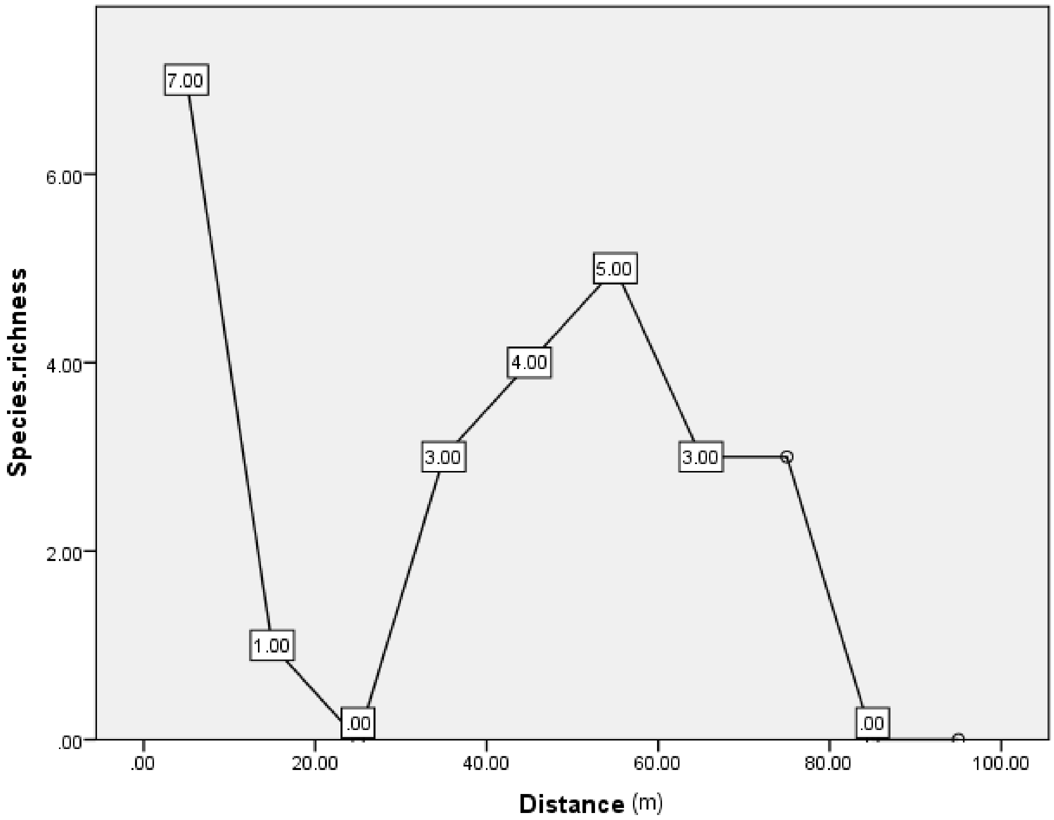

Figure 10. Trend in species richness at research site 5

4.3 Effects of topographic elements of the forest on forest edge movement

The south east aspect of research site 5 demonstrated a higher movement of forest edge (49.4m) as compared to the south west aspect (23.5m). Similar results were obtained at research site 6 where the forest edge moved by an average distance of 29.5m while in the south west aspect the forest edge moved by an average distance of 6.6m towards the grassland (Table 7). The higher movement of the forest edge occurred at the highest altitude at research site 5 (1119 m) and research site 6 (942m). The south west aspect occurred at a steeper slope at research site 5 (27°) as compared to south east aspect (25°). The same results were observed in research site 6 where the slope angle of south east aspect is 38° with south west aspect measured as 40°.The slope angle did not show any significant trend as a major factor in determining forest edge movement.

Table 7. Topographic elements and average distance of forest edge movement

Research site	**Altitude**	**Slope angle**	**Slope orientation**	**Forest edge movement from year 1975-2014**
Research site 5	1119m	25°	South East aspect	49.4
Research site 5	1114m	27°	South West aspect	23.5
Research site6	942m	38°	South East aspect	29.5
Research site 6	927m	40°	South West aspect	6.6

4.4 Effects of cutting of indigenous trees and harvesting of *Pinus patula* on forest edge movement

At research site 1the cutting of indigenous trees was observed (Table 8). Research site 1 showed a trend of negative forest edge movement from 1975-2014 and 1992-2014 (Table 3). This trend of negative forest edge movement occurred in research site 1 where 15 individual trees cut were observed during data collection. *P viridiflorum* was the most targeted plant in the forest, where three individual plants species of this genus were cut in the forest ecotone (Table 8). *A dimitiata* is the only canopy tree species cut at a diameter of 32.8. *S mundii, S zehyri, C mundiana,C ethopica, R melanophloes, P viridiflorum, S martina, D lucida,* and *C aurea* species were cut at pole size class with a diameter range of 4.5-20cm. Most of these plant species cut along the forest edge are in the subcanopy according to their diameter (Table 8).

Table 8. List of plants species that were cut in Research site 1

Species name	**Diameter**
Scolopia mundii	6.6 cm
Scolopia zehyri	10 cm
Canthium mundiana	7.9 cm
Casin ethopica	6.8 cm
Rapanea melanophloes	6.2 cm
Pittosporum viridiflorum	10.3 cm
Mytenus heterophylla	13.4 cm
Scurtia martina	6.8 cm
Calpurnia aurea	4.5 cm
Apodytes dimidiata	32.8 cm
Doyvialis lucida	19.2 cm
Doyvialis lucida	14 cm
Pittosporum viridiflora	19.6 cm
Pittosporum viridiflora	10.7 cm
Apodytes dimidiata	9.7 cm

Harvesting of *Pinus patula* was observed as one of the anthropogenic activities in the buffer zone (20m distance between natural forest border and *P patula* plantation portion) of research site 4. This site demonstrated a trend of negative movement of the forest edge from year 1975 to 2014 (measurement),1992 to 2014 (measurement) and 2002 to 2014 (measurement) where the harvesting of *P patula* is predominant. The harvesting of *P patula* affects the movement of the forest edge. Seedlings *of R melanophloes, M heterophylla, X monospora, V lanceolata and Cussonia spicata* were identified in the buffer zone (within a distance of 20.1-30m of the belt transect) of the forest. In terms of plant density there is one individual plant species of *H lucida*, *X monospora, D whyteana, M heterophylla,V lanceloata, S mundi* and *Celtis africana* identified along the forest edge from a distance of 0-20m of the transect. Open canopy gaps were observed during the assessment of research site 4 along the forest edge. The forest edge of research site 4 comprised of a thick edge with no bush clamps forming forest ecotone.

CHAPTER 5: DISCUSSION

This chapter provides interpretation of results that are presented in chapter 4 of this document. It also highlights the views of other researchers concerning what has been revealed in this research. The trend about the scale of forest edge movement of Dontsa FMU is discussed under section 5.1. The factors contributing to different characteristics of Dontsa forest ecotone have been identified and they are discussed in detail under section 5.2, 5.3 and 5.4.

5.1 Assessment of the scale of forest edge movement

The different research sites that were selected exhibited different forest edge movements towards the grassland. Expansion and shrinkage of the forest ecotone was observed as presented in chapter 4 of this document (section 4.1). The research sites with minimal disturbance show high movement of the forest edge in the buffer zone of the indigenous forest, while research sites with high disturbance demonstrated negative movement of the forest edge. This was validated by a trend of positive and negative forest edge movement over time in research sites 1,2,3,4,5 and 6. Research sites 1,2 and 4 showed some variation in terms of forest edge movement over time although negative forest edge movement was more prominent in these respective research sites (Tables 3 and 4). Research sites 3,5 and 6 exhibited positive movement of the forest edge over time. The positive movement of the forest edge as presented in section 4.1 by various research sites (Table 3 and 4) indicated that Dontsa FMU had a biotic potential for the forest edge to move towards the grassland biome. At the research sites where there was positive forest edge movement the development of a forest ecotone was the most visible characteristic common more especially in research sites 3,5 and 6. According to Everard (1992) forests expand through ecotone development and consolidation of bush clumps or a combination of the two processes. In the linear encroachment forest precursor species invade adjacent vegetation types (Everard, 1992). The invasion of indigenous species to the grassland biome was observed in Dontsa FMU ecotone with formation of bush clumps in research sites 1 and 2, with research sites 3, 5 and 6 showing a high abundance of bush clumps.

5.2 The relationship between plant species density, species richness and forest edge movement.

This research demonstrated no correlation between forest edge movement and species density at research sites 3 and 5 where there is positive forest edge movement (section 4.2). However there are plant species with a high density in the buffer zone of the indigenous forest. These species include: *D whyteana*, *A latifolius, R melanophloes*, *A facultus, R prenoides, C aurea*, *C bispinosa*, *C inerme*, *and S martina. A latifolius* was widely distributed in the forest as it was present in the first 5 quadrats of the belt transect. From a distance of 50.1 to 70m *A latifolius* was not found growing while *D whyteana* and *H lucida* were identified growing only in this specific portion at research site 3. Individual stems of *D whyteana*, *H lucida* and *S chirindensis* were identified growing in the same quadrats at research site 3 at a distance of 50.1-80m away from the forest edge. At research site 5 *A latifolius* was prominent in the interior of the forest with 1 individual stem of *A facultus* at 0-10m. *C* *inerme* and *C bispinosa* were more abundant in the interior of the forest with a density of 5 individuals per quadrat (50m² in size) at a distance of 0-10m it was also observed that these plant species are not widely distributed along the forest ecotone area (more especially in the exterior portions) where the belt transect was established. *M heterophylla* and *C aurea* are the plant species found in the forest edge (Pooley, 1994). In the latter study these plants were found growing together at a distance of 60.1-70m from the forest border showing their potential to grow in the exterior portions of the forest. *R prenoides* showed high frequency in the forest ecotone as it was represented in 4 quadrats in the forest ecotone. *D whyteana* showed high abundance in the interior of the forest with low frequency in the exterior of the forest at research site 5 (Table 5). *S chirindensis* showed the same characteristics of growing from a distance of 50.1-80m in research site 3. The biotic potential of these plants to grow in the grassland after seed dispersal was considered as an advantage for the movement of shade tolerant species to the buffer zone. According to Valladares *et. al;* (2005) shade tolerant are most adapted in the shady environment. Seed dispersal is a natural process which is also playing critical role in the encroachment of woody plants from the forest interior to the forest edge and buffer zone of the forest. The recruitment by seedlings depends on three main processes which is the production of viable seeds, the dispersal of seeds both inside and amongst plots, and the germination and establishment of seedlings (Peters, 2002).

This research also demonstrated a poor relationship between forest edge movement and species richness at research site 3 and 5 (section 4.2) of Dontsa FMU. Research site 3 showed a decline of species richness from a value of 10 to 0 at a distance from 0-100m (Figure 10) The same characteristics were observed at research site 5 where the species richness declined towards the exterior of the forest over a distance of 20-100m. This suggest that the decline of species density from a distance of 20.1m to 100m also affects the quantity of species richness in the forest ecotone. It can be highlighted that there are factors contributing to the decline of species richness in the forest ecotone. The present literature indicates a considerable reduction in tree species richness after logging, while the reasons for such reduction in richness are as varied as the forests themselves (Clark and Covey, 2012).

5.3 Effects of topographic elements of the forest on forest edge movement.

Topographic characteristics are playing a critical role in the productivity of forest ecosystem. The effect of topographic characteristics on forest edge movement is evident in research site 5 and 6 of the study area where there is SE and SW aspect in the forest patches. In research site 5 where the forest edge movement was studied at catchment level the SW and SE aspect demonstrated high abundance of plants growing in the buffer zone. According to Burton and Hopkins, (1998) slope position, slope aspect, and its inclination strongly affect microclimate and soil depth, profile development and texture and structure of the surface soil. These in turn influence the composition, development and productivity of the ecosystem (Burton and Hopkins,1998). Research sites 5 and 6 occur at high altitude and on steep slopes (Table 7), and properties that are likely to play a role in minimizing human disturbance and thereby contribute to natural movement of the forest edge. However other researchers have shown the role of altitude in promoting species richness and diversity of the forest ecosystem. Körner, (2000) mentioned that altitude is a significant factor in ecosystem diversity because it presents changes in the availability of resources such as heat and water. Researchers have explored altitudinal biodiversity patterns of plants and explained that altitude has a function in regulating species richness patterns (Kessler 2000; Oommen and Shanker, 2005).

5.4 Effects of cutting of trees and harvesting of Pinus patula on forest edge movement

The cutting of trees from the forest edge is one of the major forest disturbances taking place in the indigenous forest. The loss of trees in the forest edge is a critical issue due to the fact that it results in the loss of protective structure of the forest. This may have serious implications for shade tolerant species that grow in the forest edge when there is change of microclimate. Forest disturbances can result in alterations in forest structure, tree species composition and diversity (Chambers *et al*., 2009; Laurance & Currant, 2008). According to the foresters, the class of trees harvested are used by communities for different purposes. However it has been noted that indigenous forest takes much longer to recover after disturbance. The indigenous species take more time to grow and recover according to observations made during the assessment and monitoring of disturbed forests (Kanuka-Dasi, pers.com).

Harvesting of *P patula* was also identified as a factor which resulted in the loss of trees and crown cover where the commercial forest is established adjacent to the indigenous forest. During harvesting of *P patula,* which is a dominating commercial forest species in the Dontsa FMU, the felling of 30m trees in height is the major threat to the survival of trees growing in the forest edge. However according to DAFF guidelines for plantation of timber it is stated that where the slope exceeds 35° the distance should be 20m between the plantation and indigenous forest in order to maintain the buffer zone. This research has demonstrated that when the plantation is established closer to the forest edge the indigenous forest edge becomes more susceptible during the harvesting of *P patula* for timber. Heilmayr, (2014) stated that plantation development has resulted in the reduction of natural forests dedicated to forest product extraction. The contradictory literature on the effects of plantations on natural forests highlight two important interactions between plantations and indigenous forests: plantation forests compete for land with natural forests, but they can also require for forest products from natural forests (Heilmayr, 2014).

The negative movement of forest edge at research site 4 is consistent with the loss of forest ecotone area of 159 457.6 m^2 from 1975 to 2014 and 154 733 m^2 from 1992 to 2014 and 150 957 m^2 from 2002 to 2014. At research site 1 where 15 individual stems were cut the forest edge moved with an average distance of -197.30m from 1975 to 2014 and -2.1m from 1992 to 2014. From 2002 to 2014 the positive movement of the forest edge by an average distance of 3.6m showed that the forest was able to recovery in the ecotone region.

CHAPTER 6: CONCLUSION

The forest ecotone of Dontsa FMU has developed overtime through the formation of bush clamps along the forest edge. The development of the forest ecotone has been validated by forest edge movement data which exhibit positive movement of the forest edge and expansion of forest ecotone area at research sites 3,5 and 6 over the period. However Dontsa FMU also showed signs of forest shrinkage which resulted in the loss of forest ecotone area. The data generated by use of GIS on forest edge movement has been very useful to reveal how the forest ecotone shrinked overtime at research site 1,2 and 4.

D whyteana, *A latifolius, R melanophloes*, *A facultus, R prenoides, C aurea*, *C bispinosa*, *C inerme*, *and S martina* are the plant species occurring at relatively high densities in the forest ecotone while *A latifolius, R prenoides, R melanophloes* were highly distributed along the grassland area. Based on the findings of this research it is concluded that these plants are contributing to forest edge movement in Dontsa FMU. The encroachment of grassland by woody species revealed that some plant species have the biotic potential to adapt to the buffer zone of the natural forest, where there is a combination of grassland and forest species.

The study demonstrated no correlation between plant species density and forest edge movement at research sites 3 and 5. This research also revealed that species richness did not have a strong relationship with forest edge movement as presented in chapter 4 of this document.

Altitude and slope aspect were identified as major factors that contribute to forest edge movement at research sites 5 and 6 of Dontsa FMU. This was validated by positive forest edge movement and the high abundance of woody species forming bush clamps in the south east aspect of the mountainous escarpment of Dontsa FMU.

Cutting of trees was identified as a form of disturbance along the forest edge which contributed to the loss of the forest ecotone area in Dontsa FMU. The forest ecotone adjacent to commercial forest is more susceptible to harvesting activities. The harvesting of *P patula* was also identified as an environmental factor that resulted in the loss of forest ecotone structure due to felling of Pinus trees during harvesting operations.

Recommendations

The cutting of trees and harvesting of *P patula* in the forest ecotone should be considered as a threat in the management plan of Keiskammahoek Estate. The Department of Agriculture, Forestry and Fisheries should develop a response mechanism to deal with illegal cutting of indigenous trees which lead to a loss of forest trees and open spaces in the forest ecotone structure. This study recommends the expansion of a buffer zone of forest patches adjacent to commercial plantation (where *P patula* is planted). The harvesting of *P patula* operations which result in the loss of the forest ecotone should be monitored and regulated in line with the objectives of National Forestry Act no 89 of 1998 (section 1a). Currently the distance between indigenous forest and commercial forest is 20m (buffer zone) according to DAFF guidelines of 1980. This study recommends for the amendment of these guidelines to strengthen protection of the forest ecotone. The management of the forest ecotone is recommended as the best management practice as supported by National Forestry Act of no 89 of 1998. This paper recommends for further research on the process of forest ecotone development, and the role of soil properties and fauna in the process of seed dispersal to adjacent biomes.

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Appendices

Appendix 1. Forest edge movement data of research site 1

Research site 1	Average distance of forest edge movement (m)	Area of forest edge movement (m²)	Year
SP 1	-41	-961	1975-1985
SP2	16	144	1975-1985
SP3	9.3	121	1975-1985
SP4	-2.5	-1.296	1975-1985
SP5	-14.7	-424.4	1975-1985
SP6	8	888	1975-1985
SP7	10.8	219	1975-1985
SP8	-19.9	-858	1975-1985
SP9	31.8	676	1975-1985
Total	**-24.7**	**-1 491.4**	**1975-1985**
SP1	-62.9	-4225	1975-1992
SP2	-13.1	-676	1975-1992
SP3	-6.5	-430.6	1975-1992
SP4	-22.5	-21170	1975-1992
SP5	8	217.6	1975-1992
SP6	-13.7	-823.5	1975-1992
SP7	-35.5	-75 896.2	1975-1992
SP8	41.7	27 972.6	1975-1992
Total	**-104.3**	**-75 031.7**	**1975-1992**
SP1	-53.9	-118 164	1985-1992
SP2	8	3053	1985-1992
SP3	-10.3	-5292	1985-1992
SP4	5.9	126.6	1985-1992
SP5	-4.3	1607	1985-1992
SP6	-24.3	-95067	1985-1992
SP7	15.4	8883	1985-1992
Total	**-63**	**-204 852.8**	**1985-1992**
SP1	-81.8	-129 960.2	1975-2002
SP2	-5.5	-310 625	1975-2002
SP3	-25.9	-22 052.2	1975-2002
SP4	5	140.4	1975-2002
SP5	-4	-247.8	1975-2002
SP6	-59.5	-94 739.6	1975-2002
SP7	40.9	26 805.8	1975-2002
Total	**-130.3**	**-530 678.6**	**1975-2002**

SP1	-5	-1 352.6	1992-2002
SP2	-6	-8 977	1992-2002
SP3	-11	-7 921	1992-2002
SP4	-5	280	1992-2002
SP4	4.3	792	1992-2002
Total	**-22.7**	**-17 738.6**	**1992-2002**
SP1	-105	135 421	1975-2014
SP2	9.5	841	1975-2014
SP3	-37	26 650	1975-2014
SP4	12	203	1975-2014
SP5	-23.8	-61 629	1975-2014
SP6	47	49 670	1975-2014
Total	**-97.3**	**-192 986**	**1975-2014**
SP1	-97	-178 929	1985-2002
SP2	-6	-1482	1985-2002
SP3	13.3	4064	1985-2002
SP4	-18	-1600	1985-2002
SP5	-23.2	-101 283	1985-2002
SP6	11	4 987	1985-2002
Sp7	-8.5	-26 650	1985-2002
Total	**-128.4**	**-300 893**	**1985-2002**
SP1	-84	-205 209	1985-2014
SP2	8.5	2 827	1985-2014
SP3	-24	-23 639	1985-2014
SP4	9	115.5	1985-2014
SP5	-10.8	-1 139	1985-2014
SP6	-91	58 443	1985-2014
SP7	26.9	10 150	1985-2014
Total	**-165.4**	**-158 451.4**	**1985-2014**
SP1	-15.6	-14 450	2002-2014
SP2	24.2	16 448	2002-2014
SP3	-29	-21 904	2002-2014
SP4	13	9 457	2002-2014
SP5	-21	-6 972	2002-2014
SP6	32	27 200	2002-2014
Total	**3.6**	**9 779**	**2002-2014**
SP1	-10.8	-16 002.9	1992-2014
SP2	-15	-19 390.6	1992-2014
SP3	11.7	21 209	1992-2014
SP 4	12	5 023	1992-2014
Total	-2.1	-9 161.5	1992-2014

Appendix 2. Forest edge movement data of research site 2

Research site 2	**Average distance of forest edge movement (m)**	**Area of forest edge movement (m²)**	**Year**
SP1	13.2	6 765	1975-1985
SP2	21.5	420	1975-1985
Total	**34.7**	**7 185**	**1975-1985**
SP1	17.9	6 162.3	1975-1992
SP2	-38.9	-46 872.3	1975-1992
SP3	-16.3	-529	1975-1992
Total	**-37.3**	**-41 239**	**1975-1992**
SP1	4	95	1985-1992
SP2	-36.6	-82 369	1985-1992
Total	**-32.6**	**-82 274**	1985-1992
SP1	15.2	4 624	1975-2002
SP2	-39	-18 632.3	1975-2002
SP3	-6.5	-330	1975-2002
Total	**-30.2**	**-14 338.3**	1975-2002
SP1	-6	-121	1992-2002
SP2	32	2 652.3	1992-2002
SP3	22	485	1992-2002
SP4	-16	-248	1992-2002
SP5	40	2 304	1992-2002
Total	**72**	**5 072**	1992-2002
SP1	15.7	2 970	1975-2014
SP2	-24	-2 425	1975-2014
SP3	5.3	289	1975-2014
SP4	-19.2	-689	1975-2014
SP5	-14	-1207	1975-2014
Total	**-36.2**	**-1 062**	1975-2014
SP1	3.5	30	2002-2014
SP2	-14.5	-696	2002-2014
SP3	25	12 882	2002-2014
SP4	-12	-1 173	2002-2014
Total	**2**	**11 043**	2002-2014
SP1	-36.4	-34 410	1985-2002

Total	**-36.4**	**-34 410**	**1985-2002**
SP1	6	756	1985-2014
SP2	-25	-6 084	1985-2014
SP3	4.5	324	1985-2014
SP 4	-26	-4 900	
Total	**-40.5**	**-9 904**	**1985-2014**
SP1	32	48 841	1992-2014
SP2	-7.5	-342	1992-2014
Total	**24.5**	**48 499**	**1992-2014**

Appendix 3. Forest edge movement data of research site 3

Research site 3	**Average distance of forest edge movement (m)**	**Area of forest edge movement (m^2)**	**Year**
SP1	5	**1 681**	1975-1985
Total	**5**	**1 681**	**1975-1985**
SP1	6	217.6	1975-1992
SP2	26	3 052	1975-1992
Total	**32**	**3 269.6**	**1975-1992**
SP1	4.5	138	1985-1992
SP2	25	2500	1985-1992
Total	**29.5**	**2 638**	**1985-1992**
SP1	16.5	**8 281**	1975-2002

Total	**16.5**	**8 281**	**1975-2002**
SP1	21	**1 012.5**	1992-2002
SP2	-5	**-27**	1992-2002
SP3	-7	**-253**	1992-2002
Total	**9**	**732.5**	**1992-2002**
SP1	25	6 360	1975-2014
Total	**25**	**6 360**	**1975-2014**
SP1	-4.3	-203	2002-2014
SP3	35	**1 260**	2002-2014
SP2	15	**256**	2002-2014
Total	**45.7**	**1 313**	2002-2014
SP1	18.3	8 883	1985-2002
Total	**18.3**	**8 883**	**1985-2002**
SP1	23.4	7 876.5	1985-2014
Total	**23.4**	**7 876.5**	**1985-2014**
SP1	21.6	11 990	1992-2014
Total	**21.6**	**11 990**	**1992-2014**

Appendix 4. Forest edge movement data of research site 4

Research site 4	**Average distance of forest edge movement (m)**	**Area of forest edge movement (m^2)**	**Year**
SP1	-5.9	-855.6	1975-1985
SP2	-5.5	-206.6	1975-1985
SP3	5.6	1 156	1975-1985
SP4	8.4	1 892	1975-1985
Total	**2.6**	**1 985.8**	**1975-1985**
SP1	-11	-1 369	1975-1992
SP2	-5.3	-1 425	1975-1992
SP3	-5.6	-961	1975-1992
SP4	-6.6	-1 089	1975-1992
Total	**-28.5**	**-4 844**	**1975-1992**
SP1	6	529	1985-1992
SP2	-10.1	-1 040	1985-1992
SP3	-4.5	-915	1985-1992
Total	**-8.6**	**-1 426**	**1985-1992**
SP1	22	21 021	1975-2002
SP2	13.5	2 209	1975-2002

SP3	-7.5	-1 521	1975-2002
SP4	13	4 692.3	1975-2002
SP5	24	14 490	1975-2002
Total	**65**	**40 891.3**	**1975-2002**
SP1	21	21 978	1992-2002
SP2	14.5	2 997.6	1992-2002
SP3	17	3 875	1992-2002
SP4	26.7	12 210.	1992-2002
Total	**79.2**	**41 060.8**	**1992-2002**
SP1	-30	-133 407	1975-2014
SP2	-21	-24 025	1975-2014
SP3	-9.5	-2 025	1975-2014
Total	**-60.5**	**-159 457.6**	**1975-2014**
SP1	-34	-115 600	2002-2014
SP2	-16	-24 025	2002-2014
SP3	-29.7	-10 972.6	2002-2014
Total	**-79.7**	**-150 597**	**2002-2014**
SP1	22.6	21 462	1985-2002
SP2	11	2 256	1985-2002
SP3	24	14 882	1985-2002
Total	**57.6**	**38 600**	**1985-2002**
SP1	-20	-142 405	1985-2014
SP2	-19	-22 575	1985-2014
SP3	**-39**	**-164 980**	**1985-2014**

Total	**-78**	**329 960**	**1985-2014**
SP1	-51.4	-130 863	1992-2014
SP2	-28	-23 870	1992-2014
Total	**-79.4**	**-154 733**	**1992-2014**

Appendix 5. Forest edge movement data of research site 5

Research site 5	Average distance of forest edge movement (m)	Area of forest edge movement (m²)	Year
SP1	5	182.2	1975-1985
SP2	17.4	3 277	1975-1985
SP3	-39.5	-17 292	1975-1985
Total	**-17.1**	**-13 833**	**1975-1985**
SP1	4	132.25	1975-1992
SP2	15.4	3 136	1975-1992
SP3	12.4	3 481	1975-1992
SP4	16.5	812.2	1975-1992
SP5	5.7	2 280	1975-1992
Total	**54**	**9 841.45**	**1975-1992**
SP1	**38.2**	33 470.7	**1985-1992**
Total	**38.2**	**33 470.7**	**1985-1992**
SP1	17	2 52	1975-2002
SP2	6	256	1975-2002
SP3	13.5	3 164	1975-2002
SP4	11.25	3 364	1975-2002
SP5	17	826.6	1975-2002
SP6	5.8	2 450.25	1975-2002
Total	**70.55**	**12 585.85**	**1975-2002**
SP1	15.6	2 525	1992-2002
SP2	6.45	324	1992-2002
SP3	2.5	400	1992-2002
Total	**24.55**	**3 249**	**1992-2002**
SP1	16.2	5 184	1975-2014
SP2	7.3	264	1975-2014
SP3	14.8	3 192.2	1975-2014
SP4	34.6	6 998	1975-2014

Total	**72.9**	**15 638.2**	**1975-2014**
SP1	4.6	272.2	2002-2014
SP2	6	600.2	2002-2014
Total	**10.6**	**872.4**	**2002-2014**
SP1	13.6	2 809	1985-2002
SP2	11	240.2	1985-2002
SP3	27.4	33 672	1985-2002
Total	**52**	**36 721.2**	**1985-2002**
SP1	22.7	3 937.5	1985-2014
SP2	46	36 195	1985-2014
Total	**68.7**	**40 132.5**	**1985-2014**
SP1	18	2 652	1992-2014
SP2	5.5	676	1992-2014
SP3	21.6	38 025	1992-2014
Total	**45.1**	**41 353**	**1992-2014**

Appendix 6. Forest edge movement data of research site 6

Research site 6	**Average distance of forest edge movement (m)**	**Area of forest edge movement (m²)**	**Year**
SP1	19.3	2 652.2	1975-1985
Total	**19.3**	**2 652.2**	**1975-1985**
SP1	17.5	2 550.2	1975-1992
Total	**17.5**	**2 550.2**	**1975-1992**
SP1	1.4	248	1985-1992
SP2	1.5	25	1985-1992
SP3	2.2	272	1985-1992
Total	**5.1**	**545**	**1985-1992**
SP1	15.5	14 161	1975-2002
SP2	16.5	2 601	1975-2002
Total	**32**	**16 762**	**1975-2002**
SP1	15	13 572.2	1992-2002
Total	**15**	**13 572.2**	**1992-2002**
SP1	29.5	39 105	1975-2014
SP2	4	256	1975-2014

SP3	2.6	95	1975-2014
Total	**36**	**39 456**	**1975-2014**
SP1	32	10 712	2002-2014
Total	**32**	**10 712**	**2002-2014**
SP1	2.5	256	1985-2002
SP2	2	31	1985-2002
SP3	20	13 282	1985-2002
Total	**24.5**	**13 569**	**1985-2002**
SP1	33	22 500	1985-2014
Total	**33**	**22 500**	**1985-2014**
SP1	47	23 639	1992-2014
Total	**47**	**23 639**	**1992-2014**

Appendix 7. List of trees that were used in the past

Botanical name	**Common name**	**Uses**	**Protected rare or Threatened**
Afrocarpus latifolius	Real yellow wood	Used for timber	Protected
Afrocarpus facultus	Yellow wood	The wood is used for furniture, floorboards and roof beams	Protected
Ocotea bullata	Stinkwood	Africans use this tree medicinally, mostly the bark is used as a remedy for headache	Protected
Ptaeroxylon obliquum	Sneezewood	Sneeze wood is highly valued as a timber for fence posts and buildings	Not listed
Apodytes dimidiata	White pear	The wood is very hard and is suitable for agricultural implements and furniture.	Not listed
Zanthoxylum capense	Knobwood	Early records show that this traditional medicine was widely used, mainly for flatulent colic, stomach ache, fever, snake bites,	Protected

		toothache and as a mouthwash.	
Curtisia dentata	Assegai	The timber of the assegai is good, strong and durable and has been exploited since the earliest colonial days, particularly for wagon-making- so much so that thousands must have been felled and a well-grown mature tree is still uncommon in our forests.	Protected
Xymolos monospora	Lemonwood	Used for furniture	Threatened
Ekebegia capensis	Dogplum	It makes a good shade in the garden and it has been used as a stunning street tree.	Not listed
Celtis africana	White stinkwood	It is a good general timber suitable for making planks, shelving, yokes, tent-bows and furniture.	Not listed
Caledendron capense	Wild Chestnut	*Calodendrum capense* is a very ornamental tree, suitable for use as a shade or specimen tree in gardens and parks, also as a street tree.	Not listed
Kiggelaria africana	*Wild peach*	The hardish, pink-brown wood is a useful general purpose timber (beams, floorboards, furniture). It was once used for the spokes of wagon wheels.	Not listed