International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 4 Issue 3 || March 2015 || PP.50-55

Mapping and Monitoring Spatial-Temporal Cover Change of *Prosopis Species* Colonization in Baringo Central, Kenya

[1,] A. A. Amboka, [2,] T.G Ngigi
[1, 2,] *Department, Department Of Geomatic Engineering and Geospatial Information System, Jomo Kenyatta University of Agriculture and Technology, P.O. Box 62000-00200, Nairobi, Kenya*

ABSTRACT: *This study integrates Gis and remote sensing to detect, quantify and monitor the rate at which Prosopis species colonization has been taking place since its introduction. Multi-date Landsat 30m resolution imageries covering a period of 25 years were classified into four classes i.e. Prosopis species dominated canopy, mixed woodland, grass land and bush land and finally bare land and agricultural fields. Change detection analysis was performed using 10% threshold to identify and quantify areas where change or No change has occurred. The results indicate that the area under bare land and agricultural fields decreased at a rate of 18.22% per year from 29% in 1985 to 3% in 1990. Between 2005 and 2010 it decreased from 9% in 2005 to 5% in 2010 at a rate of 8.94% per year. Prosopis species colonization has been increasing since 1985 where it was at 0% increasing to 51% in 1990 at a rate of 58.18% per year. Between 2005 and 2010 it decreased from 56% in 2005 to stand at 44% in 2010 at a rate of 4.34% per year. The study found out that there is no threat of desertification in the study area as a result of Prosopis species colonizing the landscape. More studies to be done to identify sustainable method of controlling Prosopis species colonization to avoid more loss of agricultural land and grazing fields.*

KEY WORDS: Colonization, *Prosopis species*, Remote Sensing and GIS, spatial-temporal

I. INTRODUCTION

Environmentalist, resource managers and policy makers, are amongst the individuals who are more concerned about the threat of *Prosopis species* colonization to biodiversity and human livelihood. Species colonization is brought about by introducing an alien species that can withstand extreme drought conditions and resistant to pests and diseases. The term alien species is best described by (Richardson et al., 2000) as an introduced species, exotics, invaders or immigrants. In Kenya, *Prosopis juliflora, Prosopis chillensis*, *Prosopis velutina*, *Prosopis glandulosa* var. *glandulosa* and *Prosopis glandulosa* var. *torreyana* were introduced in the arid and semi-arid regions by the Kenyan government in collaboration with Food and Agricultural Organization (FAO) under the fuel wood and afforestation program. This was aimed at providing fuel wood to the local communities as well as combatting desertification that was a major concern in mid 1970s and early 1980s. The introduction phase was uncoordinated which resulted into unplanned massive planting of *Prosopis species* by the local communities in early 1990s. The species later on became invasive colonizing existing indigenous vegetation, agricultural and grazing fields (Mooney & Hobbs, 2000).

Prosopis species colonization has an effect of altering the accumulation of nutrients and their cycle and altering the hydrology system and carbon sequestration on bush lands and grasslands (Polley et al., 1997). Alien species colonization also is known to have major impacts on ecosystem services and natural forests and human socio-economic wellbeing. (Mooney & Hobbs, 2000). In Kenya, *Prosopis species* colonization is well evident in the arid and semi-arid regions where the indigenous woodland species have been replaced by *Prosopis species*. This changes the habit of birds and other organisms thereby reducing species richness and diversity (Dean *et al*., 2002). It is documented that bio-invasion is an important component of species extinction as a result of being outdone by the alien species (Drake et al., 1989).

Recent studies indicate that *Prosopis species* colonization drastically reduces food resources in affected areas by occupying cultivatable fields and hindering the growth of grass thereby cutting food supply to livestock (Anderson, 1996). Local communities in arid and semi-arid areas in Kenya are mainly pastoralists who are heavily affected by the rapid decline in grazing fields. Most studies have been done concerning the impact of Prosopis species invasion on livelihood with little or no attempt made to map and quantify its colonization both in space and time.

This paper aims to fill this research gap by taking advantage of rich database of remote sensing data that allows historical phenomena to be mapped and compared with the current situations. The improvement of GIS and remote sensing software's over the years has provided a cost effectives and faster means of studying *Prosopis species* colonization (Joshi *et al.*, 2003). This is of great importance to the policy makers in the decision making process, environmental conservation team in environmental management effort and local communities on how to control the colonization of *Prosopis species.*

1.1 Remote Sensing and GIS Techniques in Mapping Prosopis Species Colonization

Remote sensing plays a crucial in mapping and monitoring invasive species. Its ability to provide multispectral and multi-temporal coverage at a very cost effective way has made it the number one choice for mapping vegetation cover change over a wider geographical area within reasonable timelines (Stoms & Estes, 1993). This technology has enable researchers to conduct studies in inaccessible areas. Remote sensing offers a wider range of sensor systems such as the aerial photographs, multi-spectral scanners, satellite imagery, low and high spatial and spectral resolution and ground based spectrometer measurements (joshi., 2003).

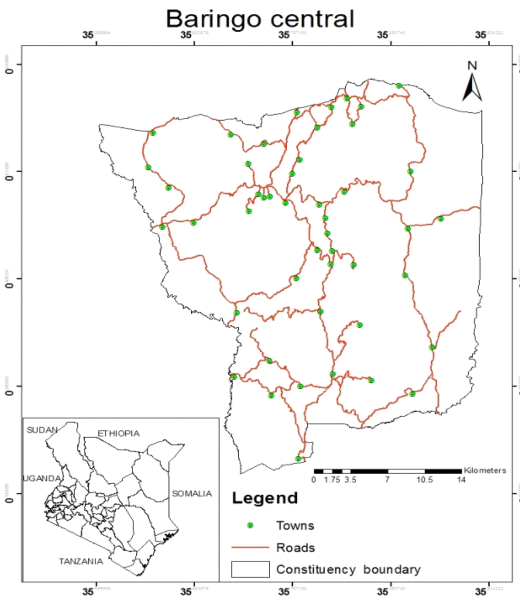
The introduction of Landsat system in 1972 provided satellite system that covered most parts of the world. These systems provided multi-date datasets that permits dynamic landscape features to be monitored hence making it possible to detect and quantify any significance vegetation cover change both in space and time. In South Africa, India and Sudan are amongst the countries where remote sensing and GIS technology has been used to map and monitor *Prosopis species* colonization. The results have provided the potential of remote sensing to detect any form of alien invasiveness (Lillesand & Kiefer, 1994).

II. OBJECTIVE

This study aimed at using geographical information system (GIS) and remote sensing (RS) technology to;

- Use remote sensing and GIS technology to map and quantify the actual area under *Prosopis species* colonization both in space and time
- Determine the rate at which colonization has been taking place within a period of 25 years

III. STUDY AREA



The study was conducted in Baringo central which is one of the constituencies of Baringo County, Kenya. It has two major towns, kabarnet and Marigat town. It has an area of approximately 588.52 square kilometer. The topographical features in the constituency are seasonal river valleys, Kerio valley and hills.

IV. MATERIALS AND METHODS

4.1 Remote sensing data and processing

This study used multi-temporal Landsat imageries acquired during the dry months of December and January of the respective years as illustrated in table 1. Other datasets used for this study include the Baringo central shape file projected to WGS 84 UTM zone 36N and GPS points used for selection of training sites and image classification.

Table1 : Remote sensing data sets used for the study

Sensor	Resolution	Path/row	Acquisition date
Landsat TM	30 X 30	P169R60	2/1/1985
Landsat TM	30 x 30	P169R60	7/1/1990
Landsat TM	30 X 30	P169R60	2/12/1995
Landsat ETM+	30 x 30	P169r60	10/1/2000
Landsat tm	30 x 30	P169r60	9/12/2005
Landsat tm	30 x 30	P169r60	8/1/2010

4.2 Image Pre-Processing

The remote sensing datasets used for this study were obtained from two different sources i.e. USGS website and department of Resource Surveys and Remote Sensing (DRSRS) under the Ministry of Mining and Natural Resource of Kenya. The datasets from USGS website were already geometrically corrected while the datasets from DRSRS were not pre-processed. The pre-processing included image registration, radiometric calibration and radiometric normalization. Ground Control points obtained from the study area were used for image rectification and registration of TM and ETM+ imageries.

A total of 50 ground control points were used for image rectification and registration. GCPs from the already ortho-rectified Landsat Tm data obtained from USGS website were also used to perform image to image registration. All the datasets were corrected with a root mean square error of < 0.4 pixel. Top-of-atmosphere reflectance was performed on all the multi-temporal datasets to reduce the error as a result of different atmospheric conditions (Van den Berg et al.,2008). To develop the different classes used for this study, land cover/vegetation cover categories and areas under Prosopis species colonization were surveyed using global positioning system during December 2014 and January 2015.

This information was used for onscreen visual interpretation to map the vegetation cover on the multi-temporal imageries. Images taken during the study period indicates that *Prosopis species* remains evergreen throughout the years during which other woodland species experience deciduousness and senescence. There are no agricultural activities taking place during the study period hence preventing the spectral reflectance of agricultural produce from interfering with the reflectance from *Prosopis species*. The spatial analysis conducted by this study focused on analyzing the total area under each vegetation cover class followed by the conversion matrix and finally analysis of the area under *Prosopis species* cover. The annual rate of each land cover class was also calculated. To develop the classes, NDVI stratification and maximum likelihood classification algorithm were used. Accuracy assessment was then performed on the classified images using a total of 250 points that were randomly generated (Landis and Koch 1977).

4.3 Normalized Difference Vegetation Index (NDVI)

NDVI index is mainly used in vegetation identification and determination of its health vigor based on the amount of chlorophyll available in the leaves. Considering that Prosopis species remains evergreen throughout the year, this study used NDVI index to map the different types of vegetation with regard to their distinctive spectral reflectance during the study period. To calculate NDVI, the visible and near-infrared light reflected by vegetation was used based on the following formulae.

Using NDVI stratification, the following classes were developed and used throughout the classification process.

Table 2 : NDVI stratification

class	Land use land cover class	NDVI STRATIFICATION
1	Bare land and agricultural fields	< 0.194
2	Grass land and bush land	0.195-0.344
3	Mixed woodland	0.345-0.644
4	Prosopis dominated canopy	0.644-1

V. RESULTS AND DISCUSSION

5.1 Mapping and Quantifying Area under Prosopis Species Relative to Other Vegetation Class

Table 3 : NDVI Stratification Results

IMAGE YEAR	MIN NDVI	MAX NDVI	MEAN NDVI	STDDEV
1985	-0.28	0.70	0.21	0.29
1990	-0.47	0.97	0.25	0.42
1995	-0.85	0.97	0.06	0.53
2000	-0.73	0.97	0.12	0.49
2005	-0.60	0.98	0.19	0.46
2010	-0.60	0.97	0.19	0.46

From Table 3 above, the minimum NDVI for study period was -0.28 while 0.98 was the maximum NDVI. From table 4: below the area under each land cover in hectare is quantified. Prosopis Dominated Canopy classes based on NDVI stratification was at 0% in 1985 increasing to 51% in 1990 and then dropping to 47% in the year 1995. It decrease to 29% in 2000 and later on increased to 56% and 44% in 2005 and 2010 respectively. Another area that is of more interest in this study is the area under Bareland and Agricultural fields that decreased from 29% in 1985 to 5% in 2010. From Table 5: 2029.5 ha of Bare Land and Agricultural field were lost to Prosopis Dominated Canopy class.

Table 4 : NDVI Results

	NDVI RESULTS											
	1985		1990		1995		2000		2005		2010	
Land use type	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%
Bareland and agricultural fields	29849.4	29	2661.29	3	4506.86	4	35148.34	34	9158.31	9	5062.512	5
Grass and bushland	41550.56	41	11524.71	11	20155.8	20	18119.95	18	12749.72	12	21046.36	20
Mixed woodland	30788.75	30	35834.94	35	29920.91	29	19275.39	19	23059.08	23	31316.82	31
Prosopis Dominated canopy	102.7356	0	52356.76	51	47796.86	47	29829.45	29	57412.15	56	44950.84	44

For visual interpretation NDVI stratification range from table 2: was used to produce the below NDVI classified images i.e. Fig. 2 and Fig.3

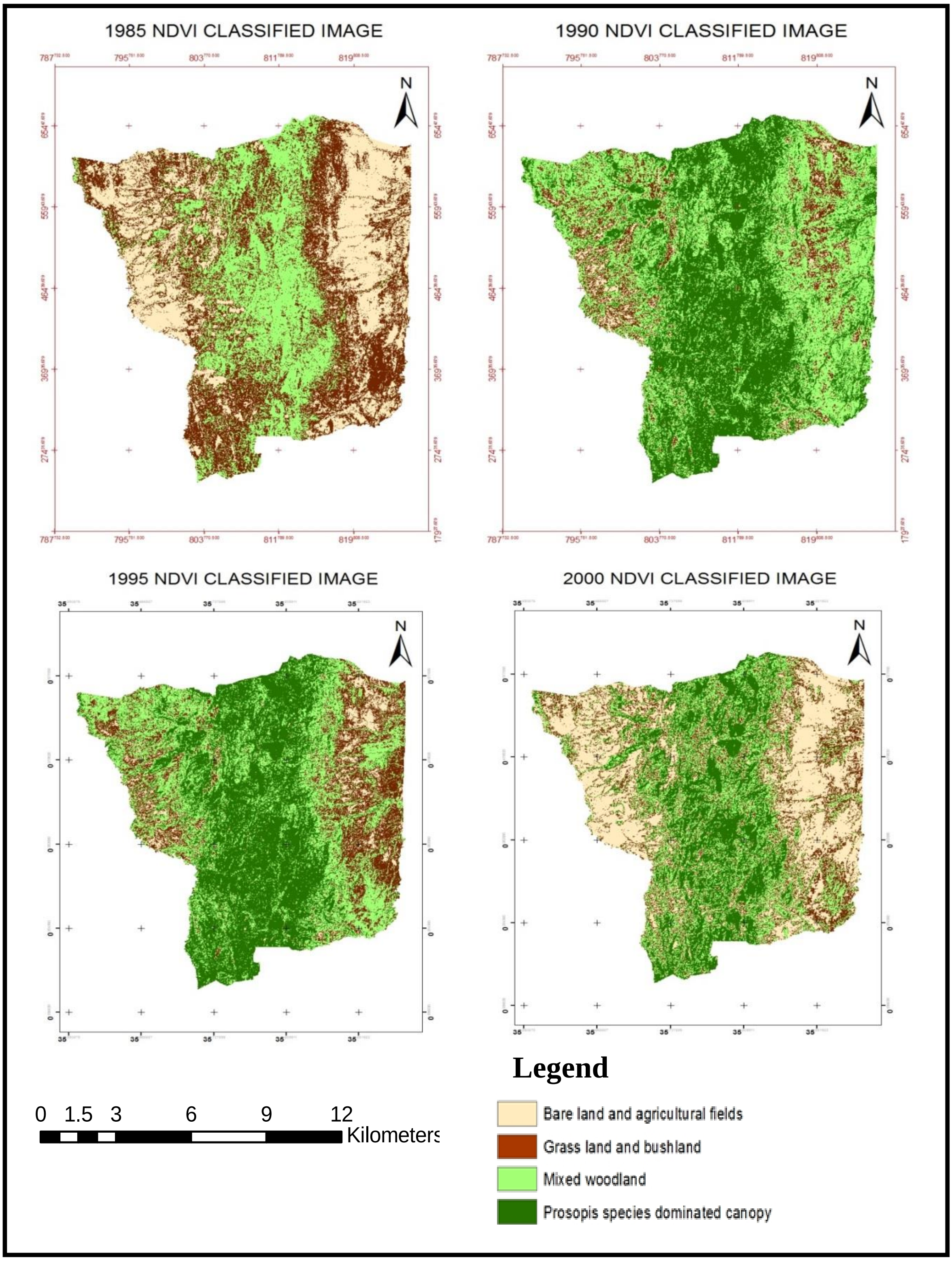


Figure 1: NDVI classified images of the study area

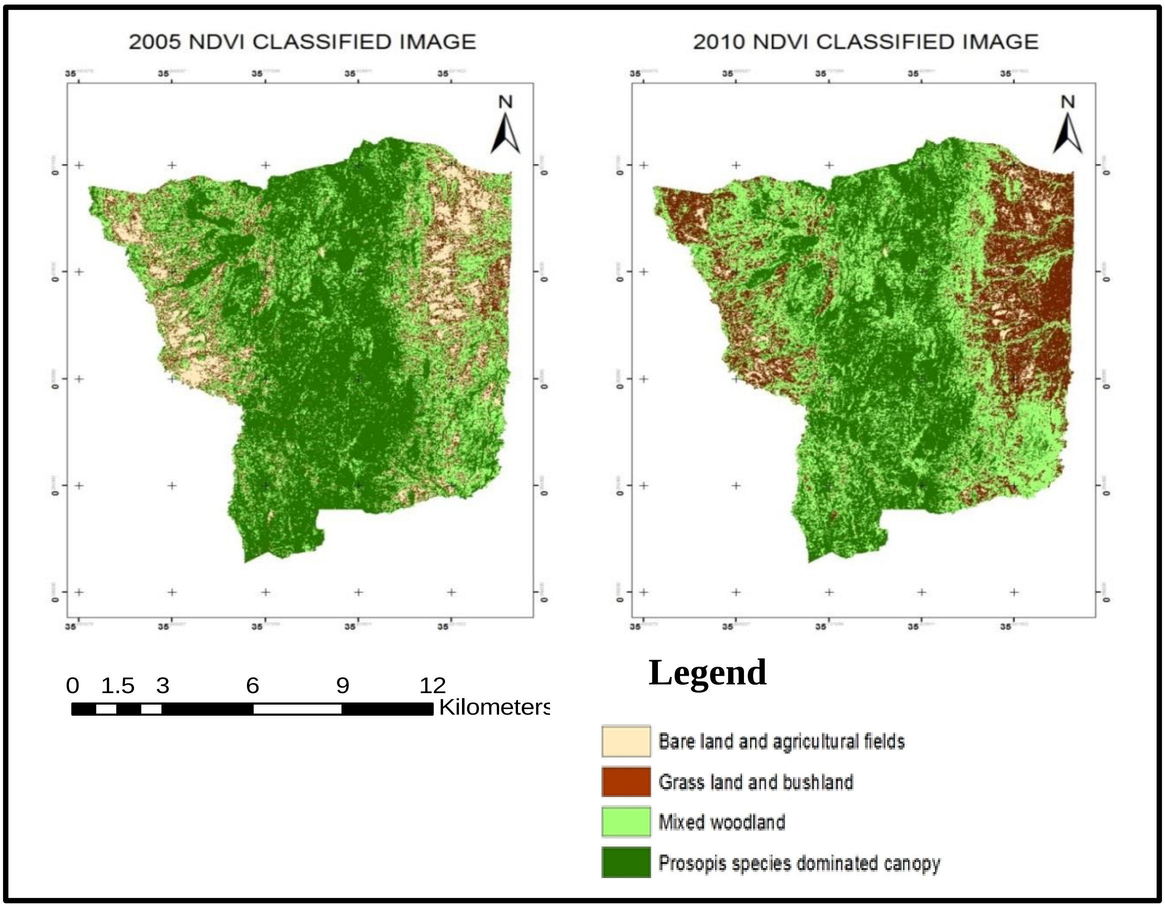


Figure 2: NDVI classified images of 2005 and 2010

5.2 Vegetation change matrix

Table 5: Vegetation Change Matrix

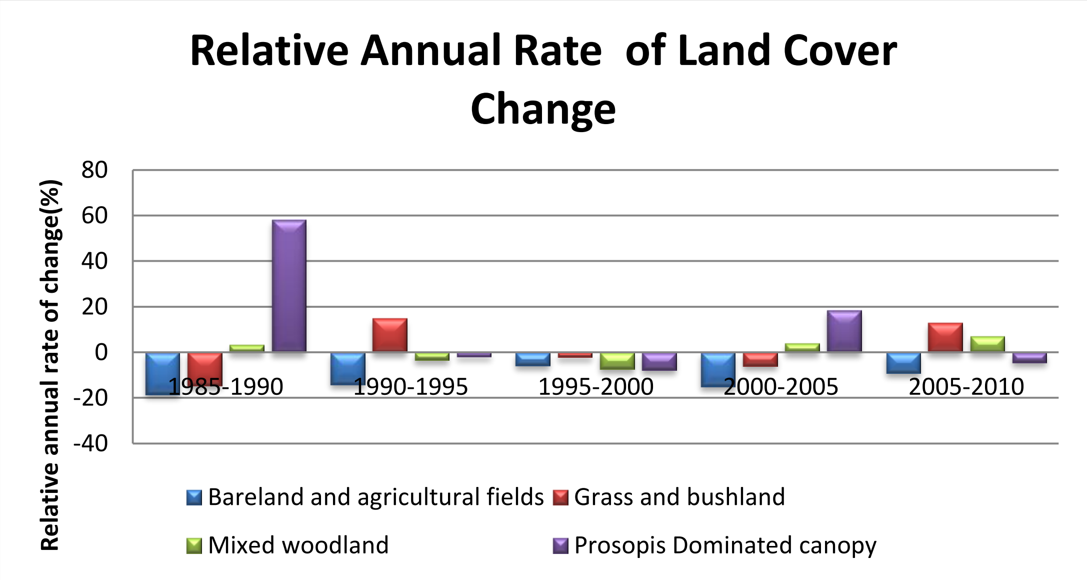
Class type	1	2	3	4	Total 2010 (ha)
1	**19051.56**	13430.25	1094.04	2029.5	35605.35
2	10456.38	**4474 .35**	1273.23	1308.6	17512.56
3	7978.05	14235.57	**8688.96**	3848.49	34751.07
4	976.95	3308.67	5976.72	**4254.03**	14516.37
Total 1985 (ha)	38462.94	35448.84	17032.95	11440.62	**102385.35**

1: Bare Land and Agricultural Fields — 2: Grassland and Bush Land
3: Mixed Woodland — 4: Prosopis Dominated Canopy

A vegetation change matrix was developed to quantify and determine the direction of change as indicated in Table 5 above.

5.3 Relative Annual rate of vegetation cove change

Figure 4: Relative annual rate of vegetation cover change



From Fig.4: The rate at which each vegetation class has been changing is demonstrated. Between 1985 and 1990 Prosopis Dominated Canopy Increased at a rate of 58.8% per year while Mixed Woodland classes increased by 3.28% per year. In the same period Bare land and Agricultural field decreased at a rate of 18.22% and Grass and Bush land decreased at a rate of 14.45%. Between 1990 and 1995 Prosopis dominated canopy classes decreased at a rate of 1.74% per year and 7.52% per year between 1995 and 2000. In 2000 to 2005 it increased by 18.49% per year before decreasing by 4.34% from 2005 to 2010.

5.4 Classification Accuracy

Error matrix was used to evaluate the accuracy of the classified images based on the 250 randomly generated points on the classified reference map. The matrix table compared the classified class values in a class by class matrix. The classification accuracy results indicated that the overall accuracy in 1985 was at 89.00% with a kappa statistic of 0.8575. In 1990, overall accuracy was at 90.00% with a kappa statistics of 0.8420. The classification accuracy reduced to 88.50% and 88.00% in 1995 and 2000 respectively with a corresponding kappa statistics of 0.8420 and 0.8417. In 2005 the overall accuracy increased to 89.50% and further increased to 90.00% in 2010 with their corresponding kappa statistics being 0.8588 and 0.8665 respectively.

VI. CONCLUSION

From the results of Table 4: it is clear that the area under *Prosopis species* colonization has rapidly increased within the 25 year period covered by the study. The Prosopis dominated canopy classes was at 0% in 1985 increasing to 51% in 1990 at a rate 58.18% per year. This rapid increase indicates how invasive this tree species is and its ability to survive extreme climatic conditions. The highest colonization took place in 2005 where the total land cove under *Prosopis species* was at 56% and later on reducing to 44% in 2010. This study will play a crucial role in determining suitable method of detecting invasive species and develop sustainable means of managing them. Gis and remote sensing technology provided a cheaper and quicker means of mapping invasive species over wider geographical. However the study was limited by the unavailability of high resolution imageries that would otherwise provide more accurate and detailed information.

VII. ACKNOWLEDGEMENT

My deepest gratitude's are directed to my supervisor Dr. Thomas Ngigi for taking me through this research, to my dear wife for financial support and to my lecturers for the roles they played throughout the study period.

REFERENCES

[1]. Richardson, D. M., Pysek, P., Rejmanek, M., Barbour, M. G., Panetta, F. D., & West, C. J., (2000). Naturalization and invasion of aline plants: concepts and definitions. *Diversity and Distributions* (6), pp. 93-107.

[2]. Mooney, H. A., & Hobbs, R. J., 2000. *Invasive Species in a Changing World*. Island Press, Washington, DC.

[3]. Polley, H. W., Johnson, H. B., & Mayeux, H. S. (1997). Leaf physiology, production, water use, and nitrogen dynamics of the grassland invader Acacia smallii at elevated CO concentrations. *Tree-Physiology*, *17*(2), 89-96.

[4]. Dean, WRJ, Anderson, MD, Milton, SJ & Anderson, TA 2002, Avian assemblages in native *Acacia* and alien *Prosopis* drainage line woodland in the Kalahari, South Africa, *Journal of Arid Environments*, vol. 51, 1:19.

[5]. Drake, J. A., Mooney, H. A., Castri, F. d., Groves, R. H.,Kruger, F. J., Aejmamek, M., & Williamson, M., (1989).*Biological Invasions: a global perspective*. Chichester: John Wiley & Sons.

[6]. Anderson, G. L., Everitt, J. H., & Escobar, D. E., (1996). Mapping leafy spurge (*Euphorbiaesula*) infestations using aerial photography and geographic information systems. *Geocarto International*, *11*(1), pp. 81-89.

[7]. Joshi, C., De Leeuw, J & Van Duren IC (2003). Remote sensing and GIS applications for mapping and spatial modelling of invasive species, Department of Natural Resources, International Institute for Geoinformation Science and Earth Observation. ITC, viewed 3 July 2008, Heywood, V. H., (1989). *Patterns, extents and modes of Invasions by terrestrial plants*. Chichester: John Wiley & Sons. http://plone.itc.nl/agile_old/Conference/estoril/papers/93_Chudamani%20Joshi.pdf.

[8]. Stoms, D. M., & Estes, J. E., (1993). A RS research agenda for mapping and monitoring biodiversity. *Int. J. of RS* (14), pp. 1839-1860.

[9]. Lillesand, T. M., and Kiefer, R. W., (1994). *Remote sensing and image interpretation*. 3rd edition. John Wiley & Sons, NewYork.

[10]. Van den Berg, EC., Plarre, C., Van den Berg, HM & Thompson, MW 2008, The South African National Land Cover 2000, Agricultural Research Council - Institute for Soil, Climate and Water, Pretoria, South Africa, Report No. GW/A/2008/86.