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EFFECTS OF SPATIOTEMPORAL CHARACTERISTICS OF POPULATION ON LAND COVER AND LAND USE CHANGES IN YALA WETLANDS OF WESTERN KENYA

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Abstract

Lands are among the most productive ecosystems across the globe. Although most families in the Sub Saharan Africa rely on wetlands for their livelihood, these ecosystems have been undergoing unknown transformations that threaten their sustainability. In Yala Wetlands of Western Kenya, about 2, 88 hectares of the original ecosystem have been lost especially to human activities. This paper analyses the effects of spatiotemporal characteristics of population on Land Cover and Land Use (LCLU) changes in Yala wetlands of Western Kenya. Geographic Information systems (GIS) and Remote Sensing were employed to achieve this objective, LANDSAT ETM for 1990, 2000, 2010 and 2014 satellite images were used. Image analysis was done in Arc GIS 10.1 and ERDAS 9.3 software packages. Analysis revealed that size of the wetland had reduced by 33 % over the 25 year period, and agricultural land had increased by over 65%. There was also an increase in population at 65% between 1989 and 2009. Inferential statistics revealed that there are significant spatial and temporal changes in land cover types due to land use changes, and that spatiotemporal characteristics of population growth in the study area have significant effect on land use land cover changes in the Yala wetland. It is concluded that human interference has led to degradation and overexploitation of Yala wetland. The study recommends that Sustainable *measures such as development of the tourism and papyrus industry, aquaculture practice and better policy implementation should be undertaken to ensure its resources are used sustainably and promote coexistence with the growing human population.*

Key words: Land Cover and Land Use Changes; Spatiotemporal characteristics; Yala wetland; Human activities; GIS and Remote Sensing.

1.0 Introduction

Globally, wetland resources make up to 9% of the earth's total land area, and are global assets of enormous value to present and future generations, since they are vital to humanity's economic and social development (Tumuhimbise, 2017). Concerns about changes in the size and quality of many of the world's wetland systems have been growing because an increasing number of wetland are being converted to agricultural or urban uses and are being affected by natural disasters such as drought (Bullock et al, 2021). The transformation from wetlands to croplands is as a result of pressure to supply more food and provide more economic income for the rapidly increasing population and to meet economic demands (Thenya and Ngecu, 2017).

1.1 Land Cover Changes

Land cover change is regarded as a fundamental component of global environmental change because of its interactions with climates, ecosystems, biodiversity and human beings (Nath, Niu & Singh, 2018). It refers to the loss of natural ecosystems such as forests, river basins, and wetlands to alternative activities such as agriculture or built up developments (Mngube, Anyona, Abuom, Matano and Kapiyo, 2019). Understanding land cover dynamics and its drivers is therefore crucial for resource management and land-use planning. Changes in land cover are exacerbated by anthropogenic activities such as agriculture and livestock rearing, forest harvesting, human settlements, and urban development among others (Comarazamy et al, 2013). A host of studies have shown the cause-and-effect mechanism between changes in global land cover and climatic factors such as rainfall and temperature (Foley et al. 2005; Mwaniki, 2015; Nath, Niu & Singh, 2018). According to Bullock et al (2021), population growth rates in Sub-Saharan East Africa are among the highest in the world, creating increasing pressure for land cover conversions. However, a comprehensive analysis on how spatiotemporal population growth affects land cover in specific environments such as wetlands is still lacking.

1.2 Land Use Change

Land-use change is a process by which human activities transform the natural landscape. It refers to how the land used had transformed for economic activities (Thapa, 2020). Land use change is responsible for increases in the human population, deforestation, food types, and demand for energy and fiber. Climate change involves global warming, precipitation, natural disasters like floods, storms, and droughts (Sun, He, Shi, Zhu & Li, 2012). Land-use impacts climate through deforestation and rapid population growth, whereas climate change impacts land use through unpredictable heavy rainfall and increasing temperature. The climate change effects on land use perceive by land use altered and land management strategies for mitigating climate change's adverse effects. For example, climate change affects crop production, which leads to land-use change. Both changes in driving forces vary in time and space. Land-use change (LUC) is fundamental to global adjustment (Zhang & Su, 2020) that directly influences climate change.

Humans have to change the land cover for centuries, but recent rates of change are higher than ever (Bullock et al, 2021; Thapa, 2020). Land-use change reflected in land cover change, the main component of Climate change, affects land-use decisions (Foley et al. 2005). It is pre-dominated by deforestation for cultivated land, and then other land-use types like built-up industrial areas. Land use and land-cover change (LULC) impact weather and climate at the synoptic scales and the mesoscale (Thapa, 2020). LUCC study provide essential data support for the research of human activities on environmental change (Parravicini et al. 2012; Wu et al. 2016).

Last three centuries, in many developing countries are moving through transition economics, increasing demand for food and energy due to a growing population has caused deforestation, cropland increased and urbanization (Onyango et al, 2021; Tumuhimbise, 2017). Several studies have demonstrated that cropland area increased and forest decreased, a similar trend of cropland sharp raised and forest area declined in India, Nepal, and other South Asia (Tian et al. 2014; Thapa, 2020). Countries in East Asia, North America, and Europe have faced land-use change due to economic and population growth. Since the past few decades, land-use change impacts on climate. The significant contribution is the precipitation cycle at a local and regional level (Mbow et al, 2019). Climate change brings unpredictability of rainfall and extreme weather events, which will increase risk in the long term. This study analysed the effect of spatiotemporal population on land cover and land use changes in Yala Wetlands of Western Kenya.

2. Materials and Methods

2.1. Study Area Description

Yala swamp is the largest freshwater inland wetland in Kenya, covering an area of 17,500 ha. It is located in the Yala delta on the northeast shore of the Lake Victoria basin coordinates extend from latitude 0º to 0º 45 North and longitude 33º55'' to 34º25. The wetlands are (Figure 3.1) at an altitude of 1,140m and 1,150m above sea level (Kenya Wetlands Forum 2006). The swamp traverses Siaya and Busia counties but the larger part of it is in Siaya County This study concentrated in Bondo, Budalangi and Boro divisions are the major administrative divisions that surround the Yala swamp wetland

The swamp was formed through the back flow of water from Lake Victoria and the flooding of rivers Yala and Nzoia, River Yala is the main source that feeds the swamp. Within the swamp there are three lakes, namely, Lake Kanyaboli (1000 ha), Lake Sare (500 ha) and Lake Nyamboyo (1 ha) Birdlife International, (2012).

2.2 Socio economic activities

Crop production has, for most households, overtaken fishing and livestock farming as the key economic activity. The present land-tenure system limits livestock movement and grazing space. Income from fishing around the lake has shrunk because of increased water pollution, over fishing and poor fishing techniques, leading to the fish depletion from both Lake Victoria and Lake Kanyaboli (Owino and Ryan 2007). One hundred twenty thousand farm families, (80% of the district"s population,) engage in crop and livestock production. In addition, 60% of the household income comes from agriculture and rural self-employment activities (Siaya District Development Plan 2002–2008). Continuous cultivation, monoculture and poor land management have increased pressure on land.

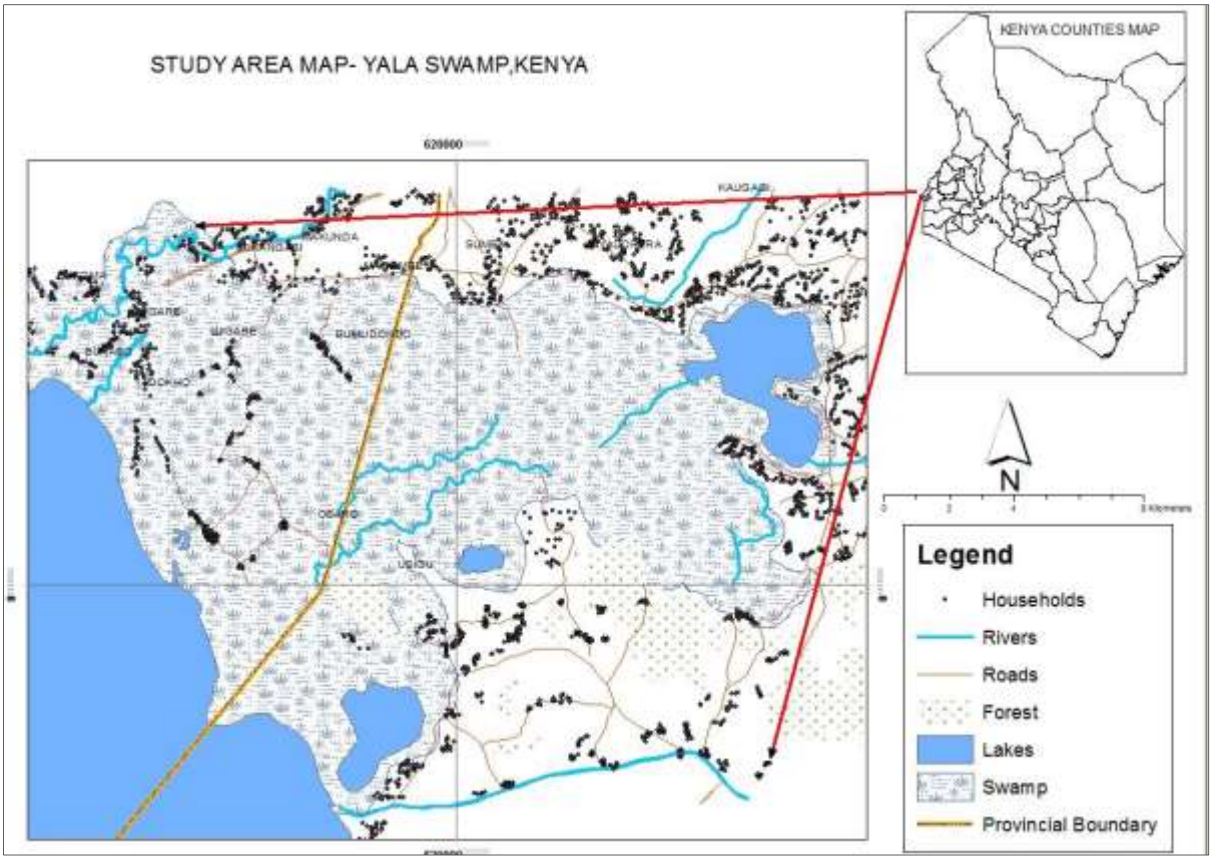

Figure 1: Yala Wetland Map

2.3 Data Sources and Data Acquisition Methods

2.3.1 Data Sources

LANDASAT-TM images for the period 1990, 2000, 2010 and 2014 were analysed. This were considered appropriate for the study due there relatively good resolution were further resampled to a higher resolution to cost effectively cover the needs of the study. 2014 satellite image was also used mainly to show the current status of the wetland

2.3.2 Sampling Frame, Sample Size and Design

The sampling frame for the study was estimated at 201869 households based on the 2019 household census, Kenya (KNBS, 2020) only an approximately 44412 of this population bearing the most effect as they live closer to the wetland and are within the set boundary of 2 kilometres created around the Yala wetland.

Fisher's (1998) formula was used to determine the sample size for this study. A sample size of 243 households was used in this study as given in the equation below.

$n = Z^2 pq/d^2$
Where:
n = The desired sample size (if target population is more than 10,000).
z = The standard normal deviation at the required confidence level of 1.96.
d = The level of statistical significance set.
p = the proportion in the target population estimated to be affected by the wetland i.e. 22%
q = 1-p, 1-0.22 =0.78

Therefore

$$n = n = \frac{(1.96)2(0.22)(0.78)}{(0.05)2} = 243.14 = 243 \text{ households}$$

Cluster sampling was used to group the respondents based on sub locations as shown in Table 2.1 thereafter simple random sampling technique was used to select 242 households interviewed within the study area.

Cluster sampling was first used to group the respondents; in this case sub locations were seen as appropriate clusters. Random sampling was then used to select 242 households to be interviewed within the study area. In each sub location the respondents were selected as given in Table 1. This was aimed at giving each sub location an equal representation in the study.

Table 1: Distribution of Household Heads Interviewed

Sub Location	Number of Respondents
Central Alego	22
West Yimbo	22
West Bunyala	22
West Alego	22
Usonga	22
South Bunyala	22
South Alego	22
East Yimbo	22
East Bunyala	22
Central Yimbo	22
East Alego	22
Total	**242**

The researchers interviewed 241 respondents (Males=192; Females=50). The generated data was entered into SPSS for analysis. T –test at 95% significant level was used to test the levels of significance of the changes that have occurred within the wetlands. This was done for year 1990 and 2000 land covers and the population percentage population change and land use change derived using the supervised classification method. The area in metres square will be used as the arrays

2.4 Supervised classification.

The study adopted ERDAS 9.3 maximum likelihood module method to undertake supervised classification. This method assumed that the training area digital numbers are normally distributed. The probability of a pixel value occurring in each class was computed by assigning the pixels to the class with the highest probability (likelihood of being a member). This was repeated for all the images and the results presented in figures. This process was aided by a Google earth image for the area, which is considered real time and ensured that the classified class is a true representation of the situation on the ground.

2.5 Change detection

Comparisons in the classified images involving the determination of the level of spatiotemporal changes between images for 1990, 2000, 2010 and 2014 were undertaken. This was done using the IDRISI CROSSTAB module. The independently classified images were compared and the results presented on as a map.

3. Findings and Analysis

3.1 Analysis, characterization and Image Interpretation Results

Four satellite images for four different years were used to achieve this objective that is the 1990, 2000, 2010, and 2014 images giving it a ten year span except for the final year 2014 used for showing recent state the wetland. The ERDAS software for image interpretation was used in the analysis of the satellite images.

3.1.1 Unsupervised classification

Unsupervised classification was undertaken and ten classes deduced from the results, these classes would later be used in defining the final classes in supervised classification. The classes identified at this point of classification were

1. Lake

2. Waters with shallow vegetation

3. Open waters in the swamp

4. Turbid water surface

5. Swamp

6. Irrigated farm

7. Rice farms with turbid water surface

8. Open grassland with exposed bare ground

9. Small subsistence agriculture

10. Exposed bare ground

The images are presented in Figures 2 t0 4

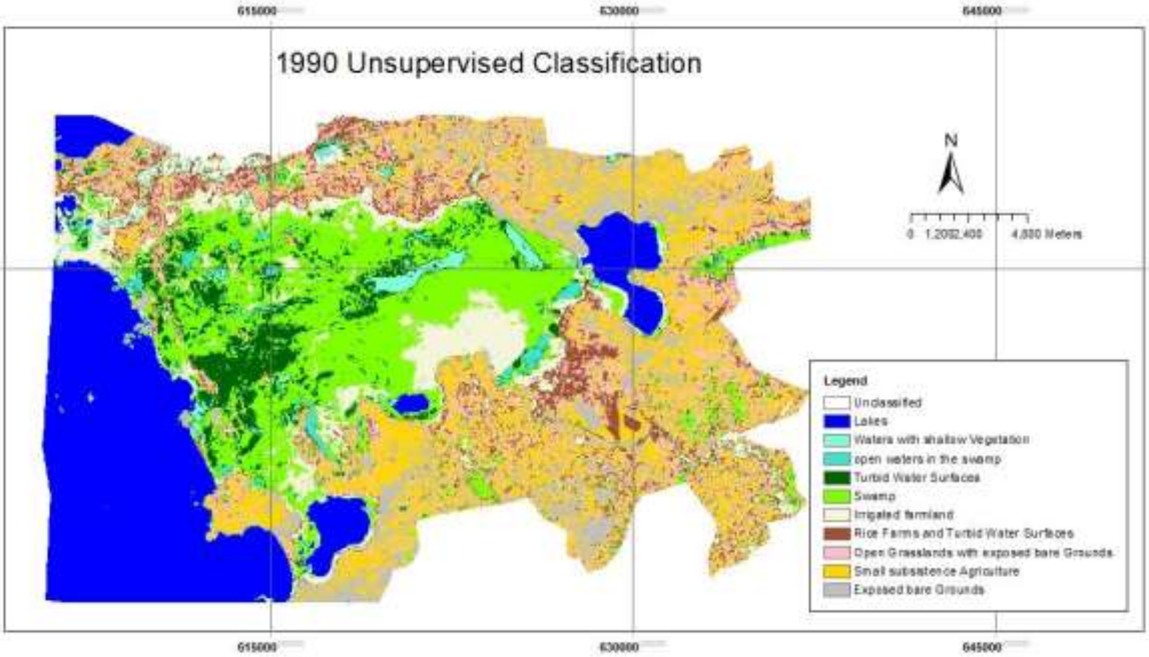

Figure 2: Unsupervised classification image results for the year 1990 in Yala wetland

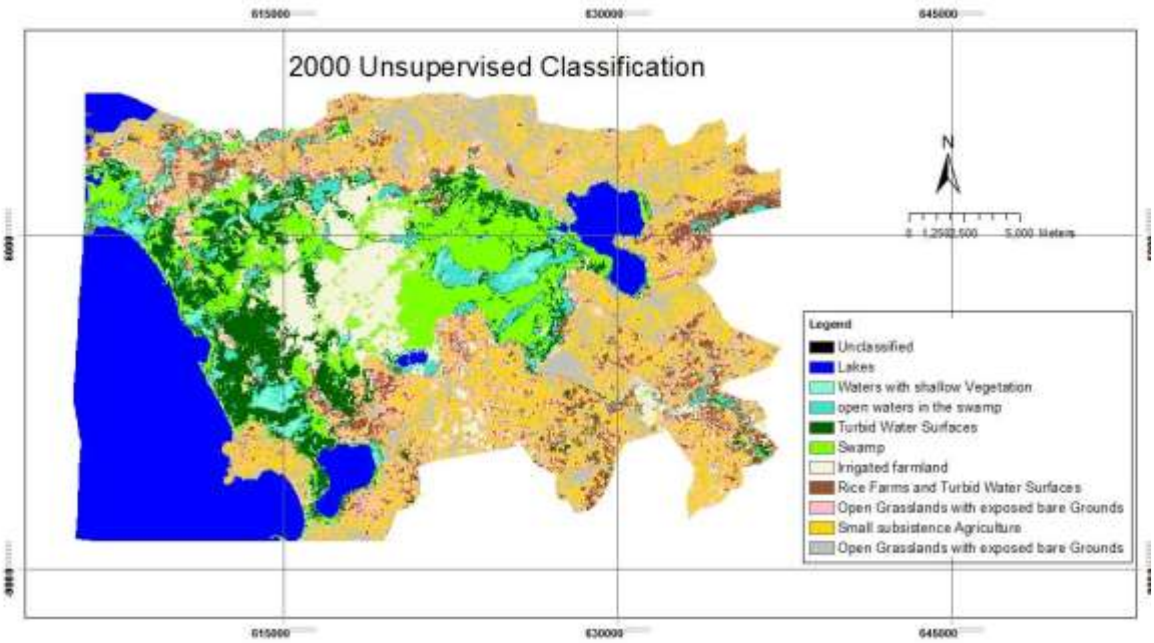

Figure 3: Unsupervised classification image results for the year 2000 in Yala wetland

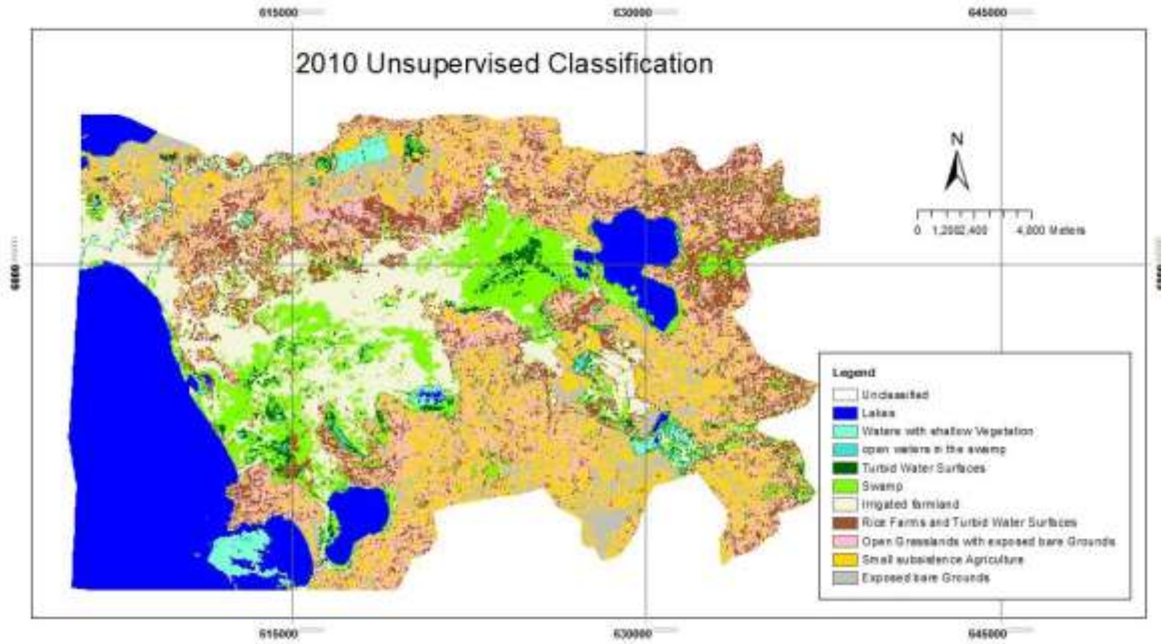

Figure 4: Unsupervised classification image results for the year 2010 in Yala wetland

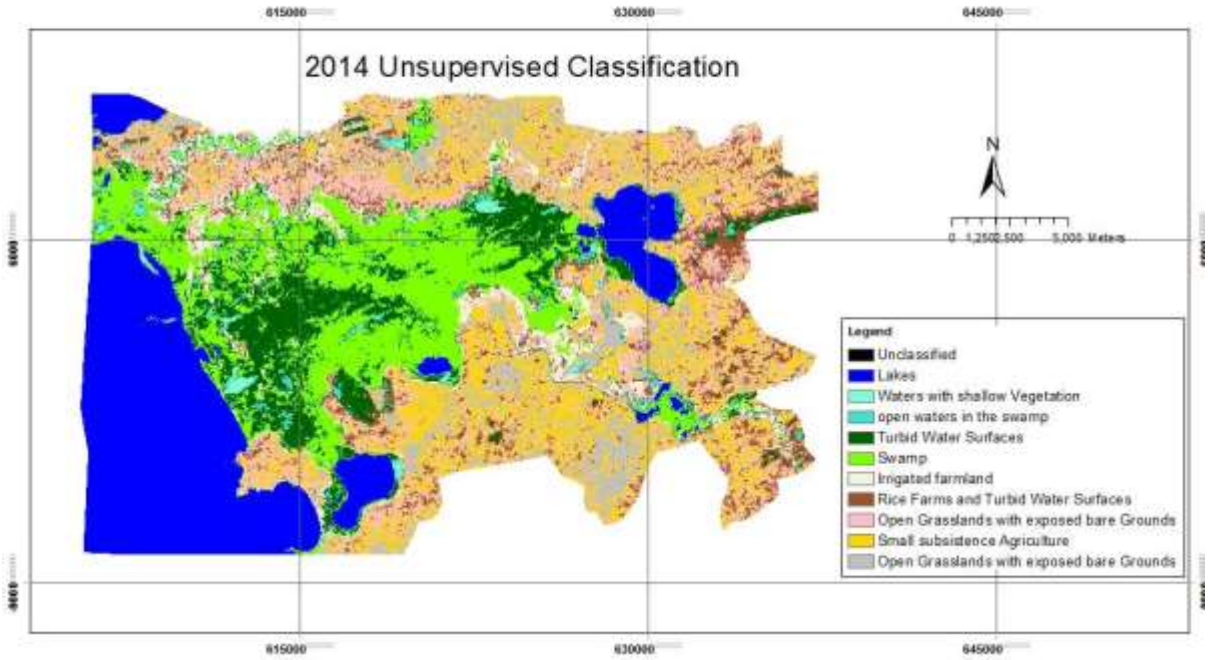

Figure 5: Unsupervised classification image results for the year 2014 in Yala wetland

3.2 Supervised classification

Supervised land classification using maximum likelihood in ERDAS 9.3 for the clipped images was undertaken with the aid of the unsupervised images. The 1990 and 2000 images were classified into six classes as compared to the 2010 and 2014 image which had seven classes. This was due to the fact the large scale rice farming had not been introduced in the area up to the year 2005, leading to the omission of the Rice paddies class in the classification of the images of the year 1990 and 2000. Figures 6 to 9 present the land use land cover classification results per year and the identified classes as:

1. Swamp/ wetland

2. Lakes

3. Shallow Water

4. Settled Areas with cultivated land

5. Cleared Areas for Cultivation

6. Grassland/Shrub

7. Rice paddy

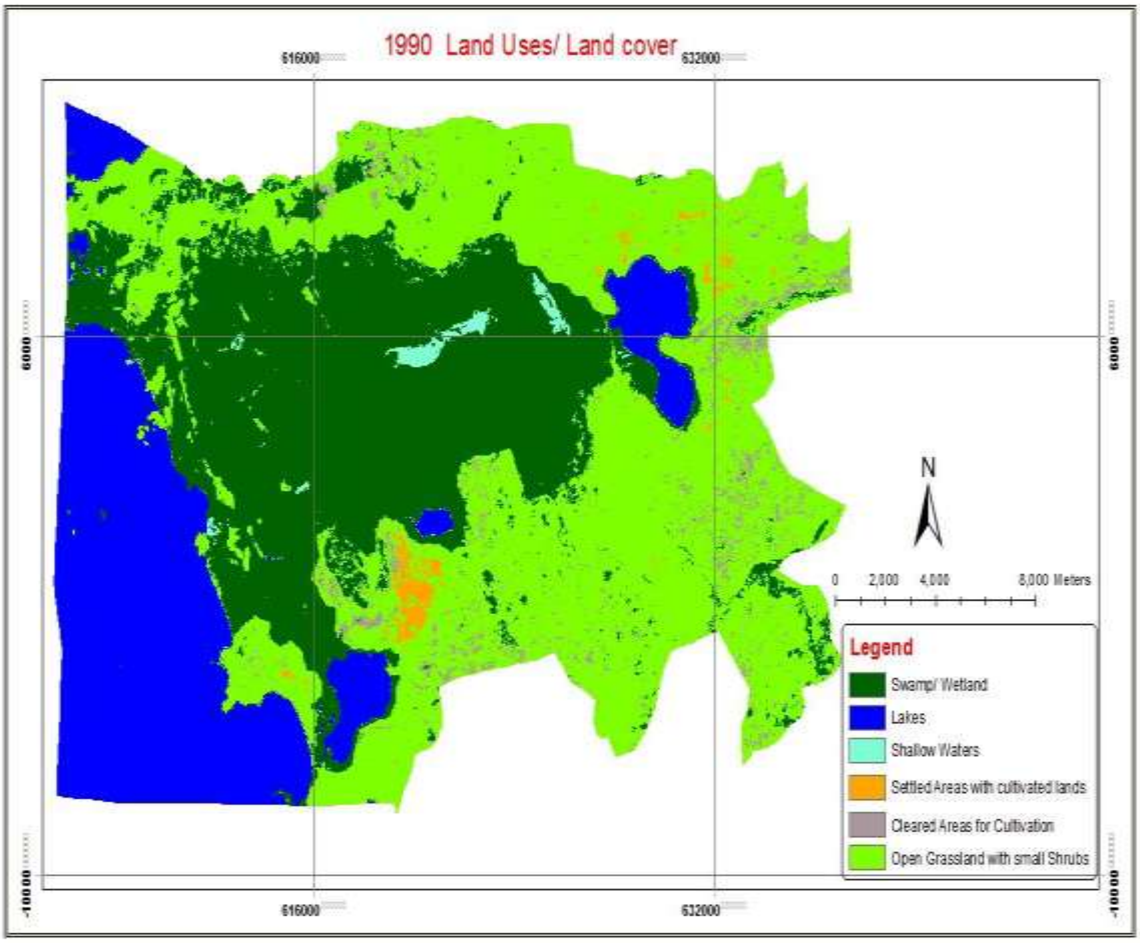

Figure 6: Supervised Classification land use land cover image results for the year 1990 in Yala wetland

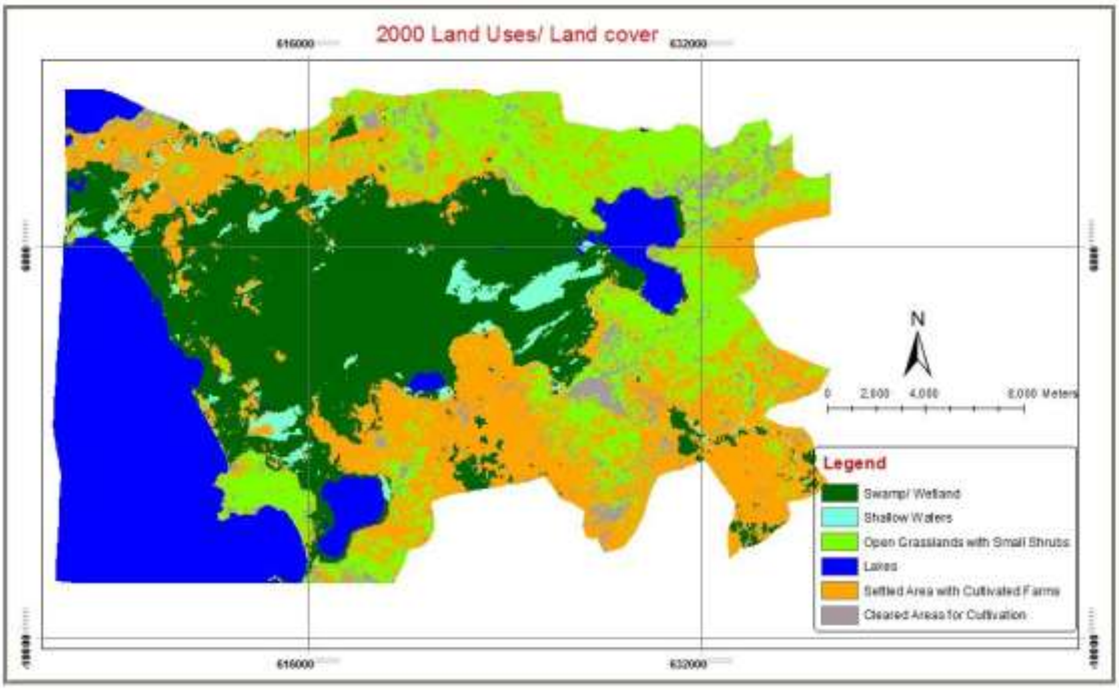

Figure 7: Supervised Classification land use land cover image results for the year 2000 in Yala wetland

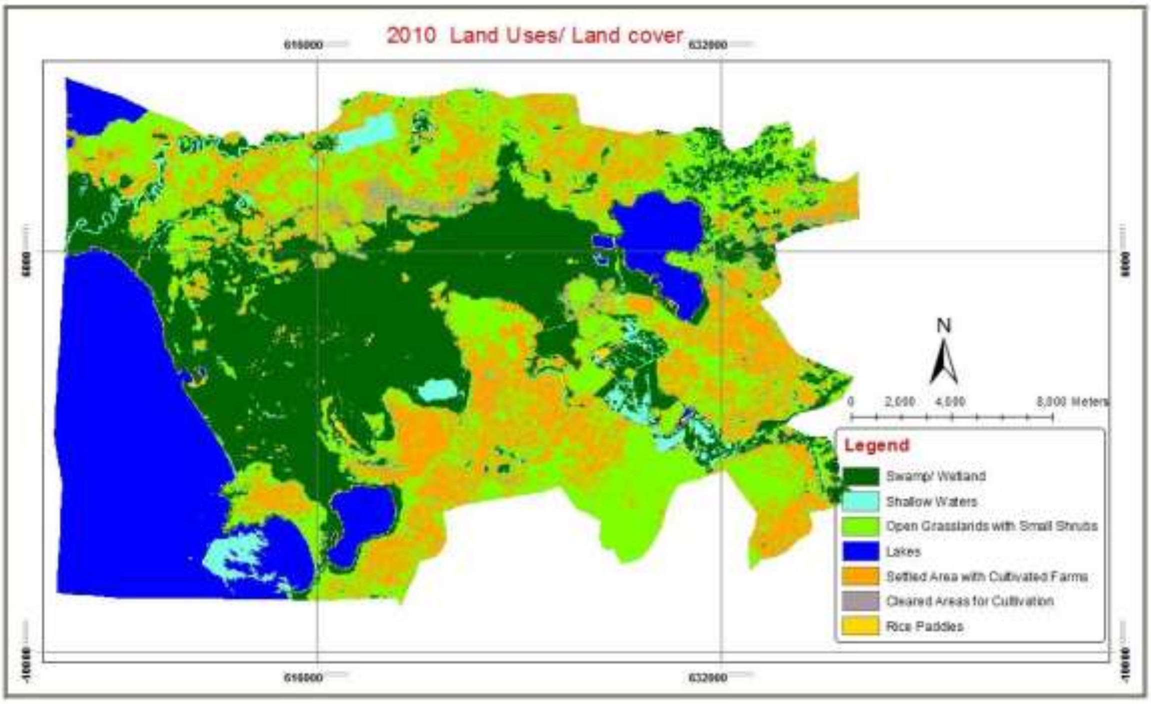

Figure 8: Supervised Classification land use land cover image results for the year 2010 in Yala wetland

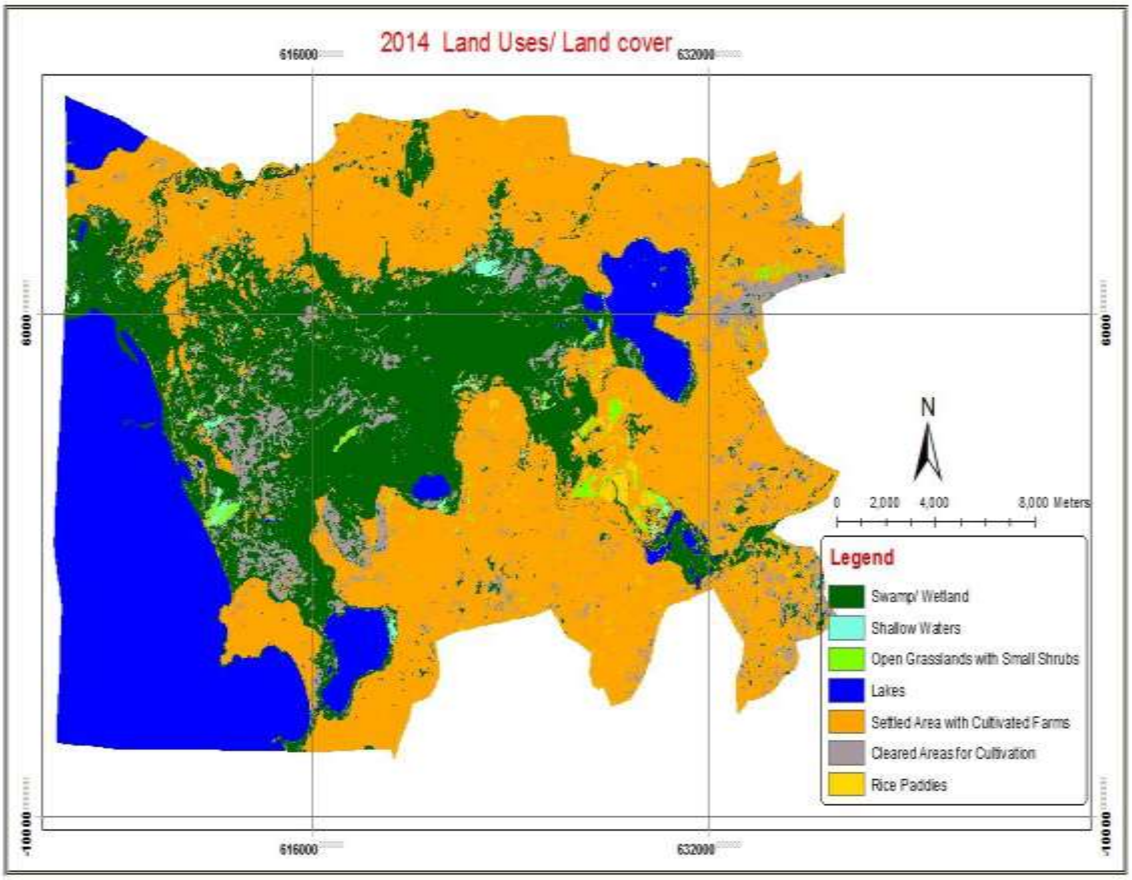

Figure 9: Supervised Classification land use land cover image results for the year 2014 in Yala wetland

3.3 Land use Land Cover Changes

The analysis of the images of 1990, 2000, 2010 and 2014 illustrates that there were major changes that Yala wetland has undergone through the 25year period. Table 2 presents the changes.

Table 2: Land use Land Cover Changes 1990-2014 in Yala wetland and its environs

	Area in Square meters				
Land Use	1990	2000	2010	2014	% Change
Swamp/Wetland	188231	167251	142018	125787	33.2
Lake	119788	120091	113281	110875	7.5
Shallow water	14342	18291	17173	13311	7.1
Settled Areas with cultivated land	44943	147684	180276	260401	50

Cleared Areas for Cultivation	14241	23661	34662	41159	65
Grassland/ Shrub	252386	104174	94397	42000	83
Rice Paddy			4124	5238	21.2

Table 2 illustrates that there was a 7. 5% decrease in the area occupied by the lakes from 1990 through to 2014. Shallow waters had a slight reduction of 7.1% in the area; this could be attributed to siltation as observed in the area waters. There was an increase in the area occupied by settled areas with cultivated farms by 50% due to increase in population, cleared areas for cultivation had an increase of 65% between the year1990 and 2014.. This was due to the fact that the study area has had a steady increase in the population as from 1990. Grassland /shrubs also decreased by 83% elucidating that most of these areas have been cleared for other land uses. Commercial rice farming (rice paddies) which introduced large scale rice farming in the area as from 2005 has been also on an upward trend increasing the area occupied by these activities by 21.2% from the year 2010 to the year 2014. Maps in Figures 10 to 13 further illustrates the changes

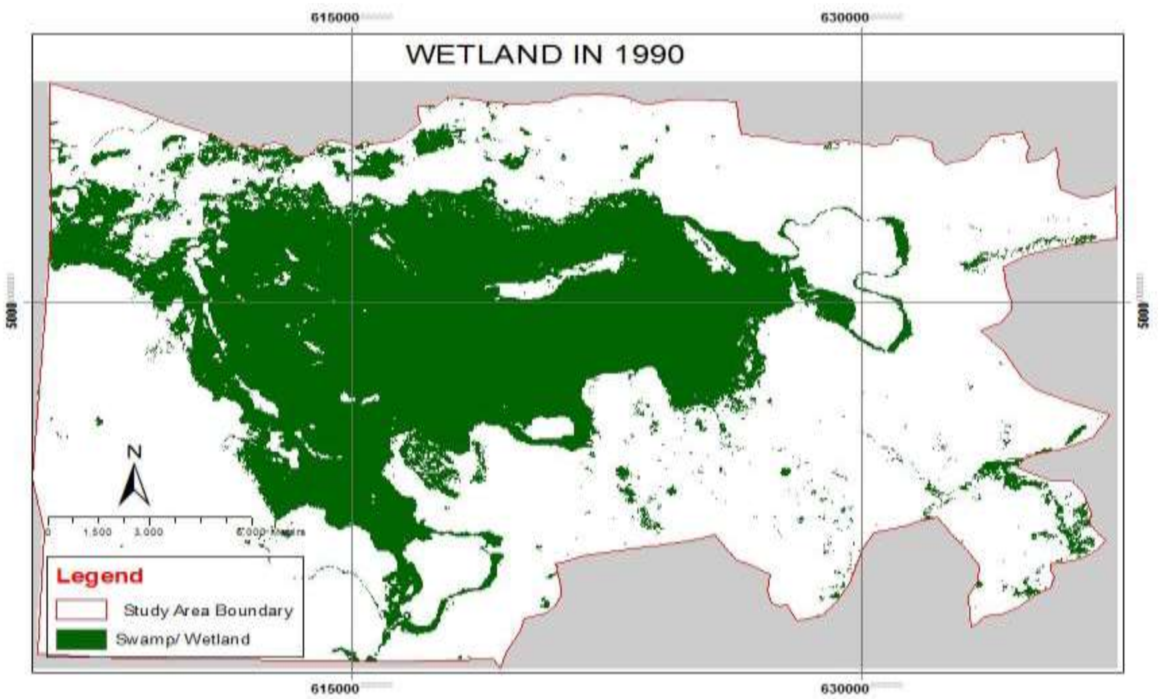

Figure 10: Area occupied by the swamp in the year 1990 in Yala wetland

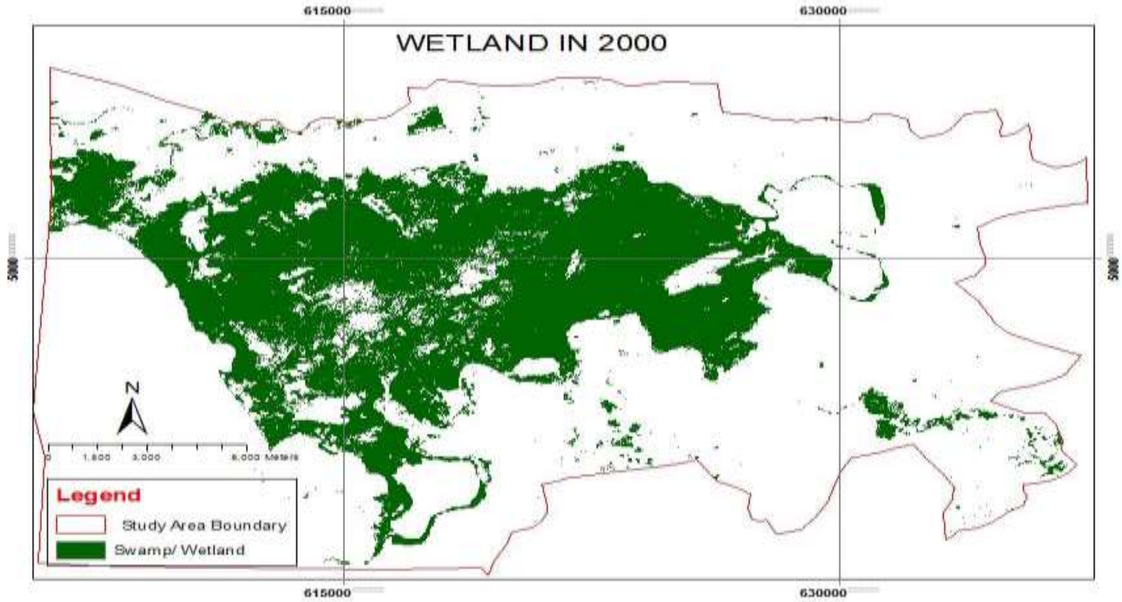

Figure 11: Area occupied by the swamp in the year 2000 in Yala wetland

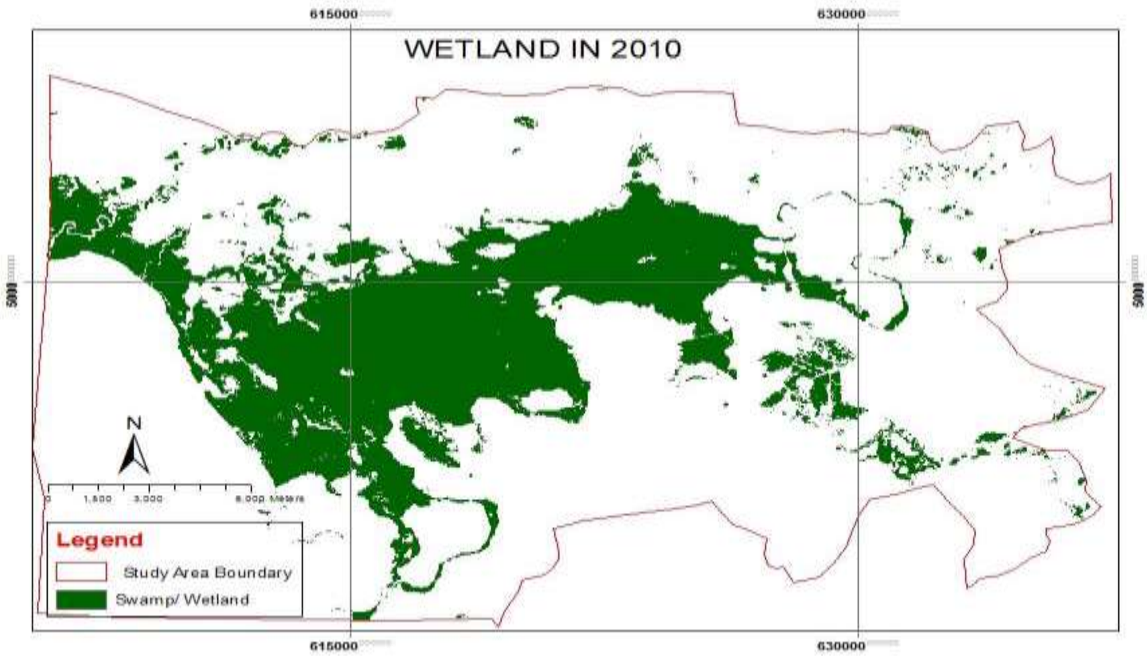

Figure 12: Area occupied by the swamp in the year 2010 in Yala wetland

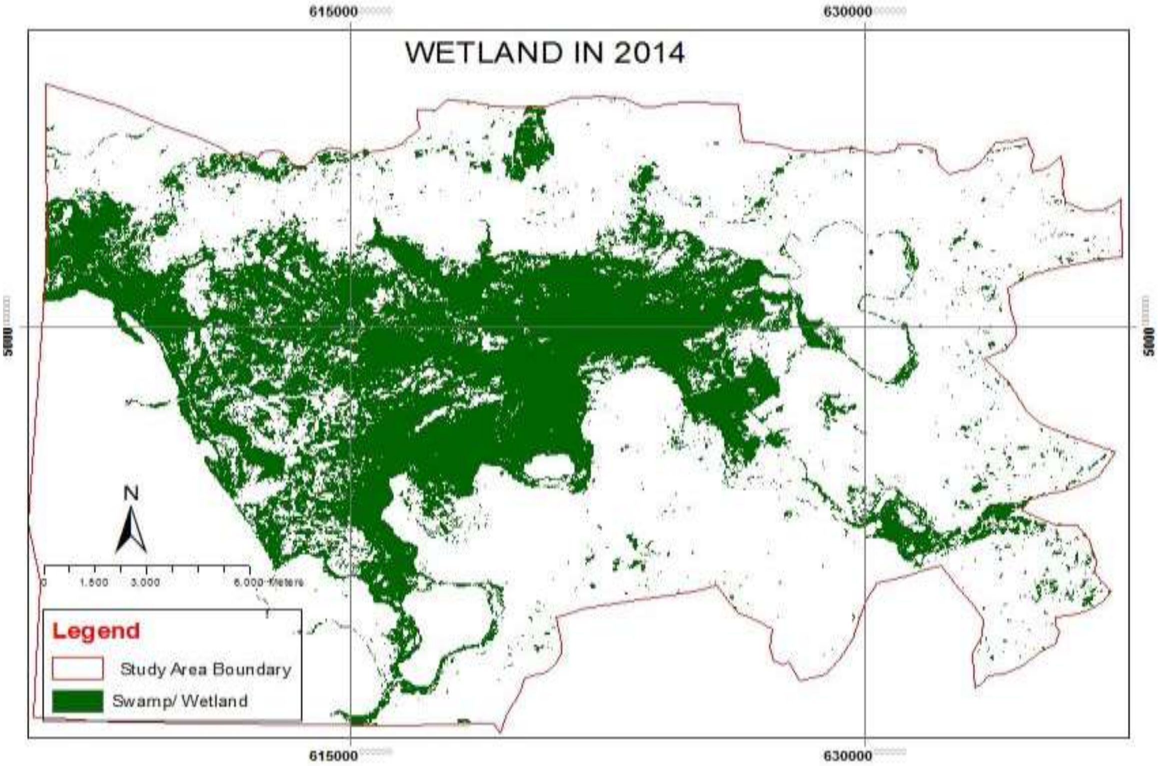

Figure 13: Area occupied by the swamp in the year 2014 in Yala wetland

The figure 14 presents the changes that have taken place within the wetland areas between 1990 and 2014. The wetland size has drastically reduced by 33.17% from the figures obtained from Land use land cover analysis in ERDAS and also tabulated in table 2.

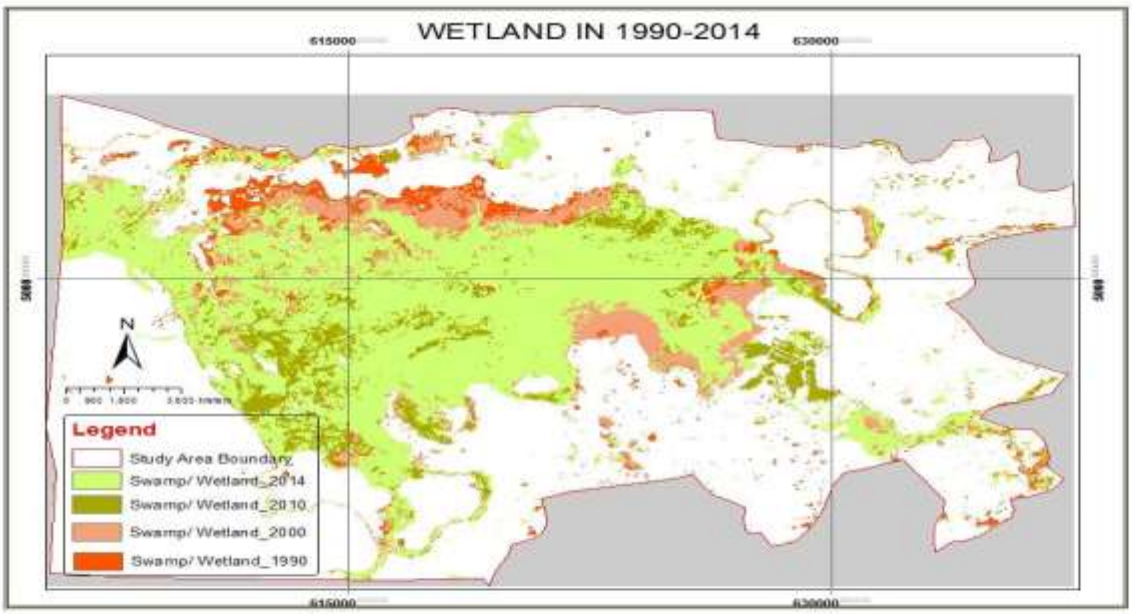

Figure 14: Area occupied by the Wetland from 1990 to 2014 in Yala wetland

Land cover classes of the study area was also analysed and presented in a map (Figure 15), with numbers 1- 7 representing land use land cover classes while 8 represents the unchanged areas over the study period

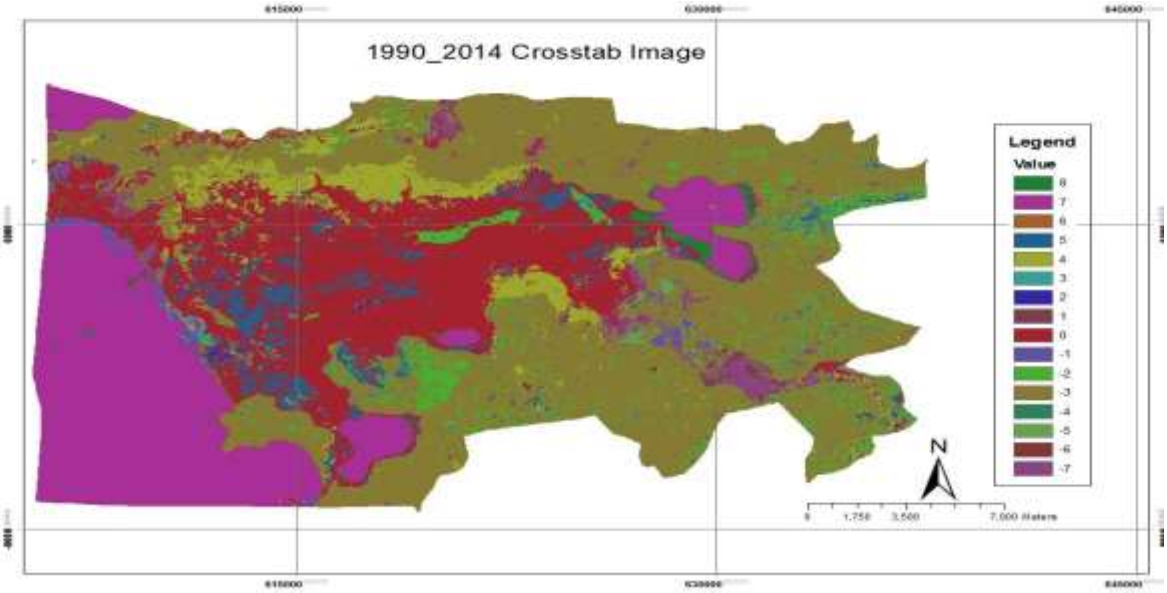

Figure 15: Change detection results 1990_2014 images in Yala wetland

3.3.1 Testing of Hypothesis HA1

The hypothesis that there are significant spatial and temporal changes in land cover types due to land use changes in the Yala wetland was tested using the T-test function in SPSS. Using the area occupied by the different land uses in 1990 and 2014 as the variables (Table 1), the hypothesis was accepted (t=0.9223; p=0.000).

3.4 Population change dynamics and Land Use Land Cover Change

Based on the 1989, 1999 and 2009 household study in Kenya, the estimated population for the areas within the study areas were as represented in the Table 3. The population of the following locations was used in defining the study area population due to the fact that they lie within the boundaries of the study area and within five kilometers from the boundary of the wetland West Yimbo, West Bunyala, South Bunyala, Usonga, West Alego, Central Alego , East Yimbo, South Alego and East Alego.

Table 3: Number of households in study Area from 1989-2009(KNBS, 1989, 1999, 2009)

Sub Location	1989	% Change	1999	% Change	2009	% Change
Central Alego	27801	47	40897	76	51564	52
West Yimbo	16072	70	27456	27	35128	55
West Bunyala	13387	51	20375	54	31421	66
West Alego	28517	50	42808	17	50356	61
Usonga	11059	79	19814	65	30238	78
South Bunyala	16858	60	26853	76	35126	49

South Alego	22034	20	25582	79	32156	35
East Yimbo	11567	65	19432	77	25189	68
East Bunyala	6301	38	14901	16	20354	95
Central Yimbo	6964	86	12176	75	16234	53
East Alego	43305	46	63675	90	70125	43
Total	**205855**		**313969**		**397891**	**65**

The human population in the study area has been on a continuous steady increase of 83% since the 1989. This increase has direct effects on the wetland and the land use land cover changes. These can be supported from the interpretation of the satellite images in Figures 14 where there was a continuous increase in settled areas at 50% with cultivated farms, open grasslands with small shrubs and cleared areas for cultivation as compared to wetland/ swamp class was reducing in size over the 24 year period.

3.4.1 Testing of hypothesis HA2

Using the total percentage change in population and in land uses, a T-test analysis was calculated to test the hypothesis that spatiotemporal characteristics of population growth in the study area have direct linkages on land use land cover changes in the Yala wetland. The hypothesis was accepted (t=0.9126; p=0.000).

4. Discussions

The study has revealed that that spatiotemporal characteristics of population growth in the study area have direct linkages on land use land cover changes in the Yala wetland. According to Bičík et al (2015) as well as Thenya and Ngecu (2017), demographic variables like growth rate are among the frequently cited underlying variables in land use and cover changes, which recur here in the Yala swamp as well. Most of land use and cover change studies have focussed on deforestation relative to wetlands degradation, but valuable lessons by can be drawn from these deforestation studies on land cover change (Bullock et al 2021; Mngube et al, 2019; Nath et al, 2018). Similar lessons were learnt by Bičík et al (2015) in the Czech Republic Tumuhimbise (2017) in Namulonge wetland in central Uganda, as well as Chi and Ho (2019) in the USA.

From the statistical analysis, it is clear that population and agriculture have a clear relationship as determinant of wetland land cover change. Among the demographic variables analysed, the major ones are identified as household number, population and household densities, which are directly related to swamp accessibility. Overall, areas characterised by large swamp conversions have high demographic densities and wetland accessibility. The large swamp area, good soils, good infrastructures and easy terrain among other factors attracts more people in the swamp area hence more conversions especially in the northern section. Similar observation have been made by other scientist on effect of demographic variables in a particular area (Govindaprasad & Manikandan, 2014; Kanianska, 2016; Onyango et al, 2021). In Yala swamp, the area along river Nzoia north of the swamp have in particular large conversions, which are attributable to higher population and household densities coupled with easy and large swamp accessibility. This exerts high conversion on the swamp. In order to convert the swamp into farming area, several factors are at play among them household labour supply is critical, which is a constraint in low population density areas.

5. Conclusion

This study analysed the effects of spatiotemporal characteristics of population on Land Cover and Land Use (LCLU) changes in Yala wetlands of Western Kenya. Geographic Information systems (GIS) and Remote Sensing were employed to achieve this objective, LANDSAT ETM for 1990, 2000, 2010 and 2014 satellite images were used. Image analysis was done in Arc GIS 10.1 and ERDAS 9.3 software packages. This study highlights the fact that the drivers of land cover change in the Yala swamp are numerous although the need to meet domestic food security and other livelihood aspects like income are more significant. It is concluded that human interference has led to degradation and overexploitation of Yala wetland and its resources leading to a decline in key ecosystem services that the wetland provides.

6. Recommendations

The study recommends that Sustainable measures such as development of the tourism and papyrus industry, aquaculture practice and better policy implementation should be undertaken to ensure its resources are used sustainably and promote coexistence with the growing human population.

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