INTERNATIONAL JOURNAL OF
SCIENCE ARTS AND COMMERCE

Dynamics of resource utilisation in a tropical wetland, Yala swamp, Lake Victoria basin- Statistical analysis of land use change

Thuita Thenya[a,*], Wilson Mwaniki Ngecu[b]
[a]Department of Geography & Environmental studies, and [b]Department of Geology
University of Nairobi, P. O. Box 30197-00100, Nairobi, Kenya

Abstract
The study analyses the determinants of land use change in a tropical wetland under utilisation by high density indigenous population located on the edge of Lake Victoria, Kenya. To accomplish this population census and household data is integrated statistically with derived remote sensing data. The main drivers of land use and cover changes are identified as population densities and household numbers. Farming is the most important wetland utilisation activity. It takes 95% of the households wetland land holding and supply more than 70% of the domestic food needs. Remote sensing data indicate progressive opening of the swamp, especially in the high population and more accessible northern side of the swamp. The swamp conversions are expected to increase with intensification as a function of the household densities under increasing population. The results offered a significantly high co-validation ((>90%) between the statistically computed land use change (11,696 ha) and remote sensing derived land cover change (11,735.44 ha).

Keywords: Conversions; Household density; Land cover; Land use Change drivers; Population density; Wetland;

1. Introduction

The global distribution of wetland varies widely while 6-7% is covered by wetlands, 44% of the wetlands are located in the northern latitude, 30% in the tropical and sub-tropical of which 30%

* Corresponding author.
Dr. T. Thenya;
Tel.: +254 721 471 082
Permanent (Current) address: Department of Geography & Environmental Studies, University of Nairobi

occur in arid and sub-arid ecosystems (Lehner and Doll, 2004;Melton et al, 2013). Geographically, about 44 % of global wetlands occur in the high northern latitudes (OECD, 1996) where they can be influenced by permafrost controls on hydrology (Woo and Winter, 1993; Woo and Young, 2006). The remainder of global wetlands are primarily located in the tropical and subtropical humid regions; of those, about 30 % occur in arid and sub-arid areas (OECD, 1996). The major proximate cause of wetland conversion emanates from agriculture development with population and economic development providing important underlying causes (Asselen et al 2013). For example in China, Luan and Zhou (2013) notes that 90% of the Honghe National Nature Reserve Ramsar site has over 30 years period (1975-2006) been transformed into agriculture landscape. According to Asselen et al (2013), most of the global wetland losses have taken place in the northern latitude with losses as high as 80% in some places with most of these losses at the end of 19th century and early 20th century. In the tropics there is a steady rise in wetland lose mainly attributed to a combination of agricultural development with underlying high population growth rate and urban development (Daniels and Cumming, 2008; Verhoeven and Setter, 2010; Asselen et al, 2013; Govindaprasad and Manikandan, 2014; Nasongo et al, 2015).

The Lake Victoria Basin are very often used for agricultural activities to supply food at domestic level and raise income, which translate to wetland loss (Johnson et al., 2000; Mugo and Shikuku, 2000; Gichuki et al, 2001; Kairu, 2001; Mwita et al, 2012, Turyahabwe et al, 2013; Nasongo et al, 2015). In addition, the Lake Victoria basin is characterised by high population, which translate to high demand for natural resources including on wetlands in the basin. The allocation of some 10,000 ha in Yala swamp through leasing agreement by the government for large-scale farming will lead to reduction of available areas for farming consequently resulting in increased pressure on the remaining swamp area. Several studies have been undertaken in Lake Victoria basin on assessing land cover changes but there was no attempt to link them to land use change drivers (Otieno et al, 2001; Kwast, 2002).

Landscape changes are dependent on a complex interaction of factors combining environmental and socio-economic factors that vary from different geographical location (Bičík et al, 2015). The foundation of land use theory goes back to 19th century von Thuenen (1966) using of cropping zone and distance to market as factors influencing land sue change. However, this school of thoughts that was mainly based on spatial economic does not consider biophysical and socio-economic factors affecting land use patterns. Other factors like population densities have been backed by various scientists (Boserup 1965; Binswanger and McIntire, 1987; Pingali et al, 1987). Furthermore, it is noted that several other drivers like soil fertility and policies affect land use and land cover change.

Demographic factors as main driver of land use change has received great interest from various scientist (Hardin, 1968; Stonich 1993; Brown, 1994; Rudel and Roper, 1996). The effect of demographic factor depends on geographical area particular settings, which include level of agricultural technology, society governance system on natural resources, land availability and population growth rate among others (Bičík et al, 2015; Pender, 1998; Jones, 1988; Schelhas, 1996). It is notable that among the many drivers identified population density is important is land sue and cover change research (Huigen, 2004; Govindaprasad. and Manikandan, 2014). Several studies dating back to 19th century have documented that increase in agricultural activities is directly associated with increasing population demand for farming land, settlement and infrastructures development. However, most research on land use and cover changes have focussed mainly on deforestation leaving a glaring omission in wetland land cover changes. According to Reid et al *(*2004) and Younos, and Parece (2015), wetland studies have concentrated on ecological studies, utilisation and regulatory framework and their possible impacts but not on the drivers of land use and cover change.

In addition to the local drivers discussed above, other drivers include international frameworks like the international Monterey Fund (IMF) trade liberalization provisions that affect use of land at the local level. In addition, natural extreme weather events like drought and floods act as broad-scale determinants of land use change (Turner *et al.,* 1989). It is noted that all these drivers do not work in isolation but form complex interactions involving both proximate causes like agriculture and underlying factors like policies (Geist and Lambin, 2002).

According to Bičík et al (2015) land use and cover changes studies are highly interdisciplinary involving a combination of natural, spatial, remote sensing and social sciences. This is necessary and helps in uncovering the complex interaction of anthropogenic activities and natural factors that drive land-use/land-cover changes. Identification of household and remote sensed data integration scale is often a challenge, however use of administrative units have proved useful and practical in several studies as such units contains other useful data like demographic and household (Green and Sussman, 1990; Pfaff, 1996; Wood and Skole, 1998).

The objective of this paper is to analyse demographic data and their relationship with social-economic parameters and its influence on satellite derived land cover changes.

3. Study area

2.1. Biophysical conditions

The Yala wetland is located between rivers Yala and Nzoia , 0^0 07' N – 0^0 01' S / 33^0 58' – 34^0 15' E (Fig. 1) in Lake Victoria basin comprising 17,500 hectares (Aloo, 2003). In terms of vegetation, the swamp is comprised of several species of cyperus including *papyrus, dives, exaltatus* and *distan.* Three lakes are located within the wetland these are Lakes Sare, Namboyo and Kanyaboli (Fig. 1), which contain some endemic fish species that are at the risk of disappearing from Lake Victoria (Njiru et al 2005, Ogello et al, 2013). In addition several species of avifauna and mammals are also found in the swamp. The Yala swamp covers both Busia and Siaya Counties and falls within the following ward, Bunyala Central, Bunyala East, Bunyala North, Bunyala South, Bunyala West in Budalangi sub-county, Busia County. Other in Siaya county, Ugenya sub county include , Central Alego, Khajula, South Central Alego, South West Alego, South Alego, Usonga, Central Yimbo, East Yimbo, North Yimbo and West Yimbo ward. The average population density is 332km^2 according to Central Bureau of statistics, 2009.

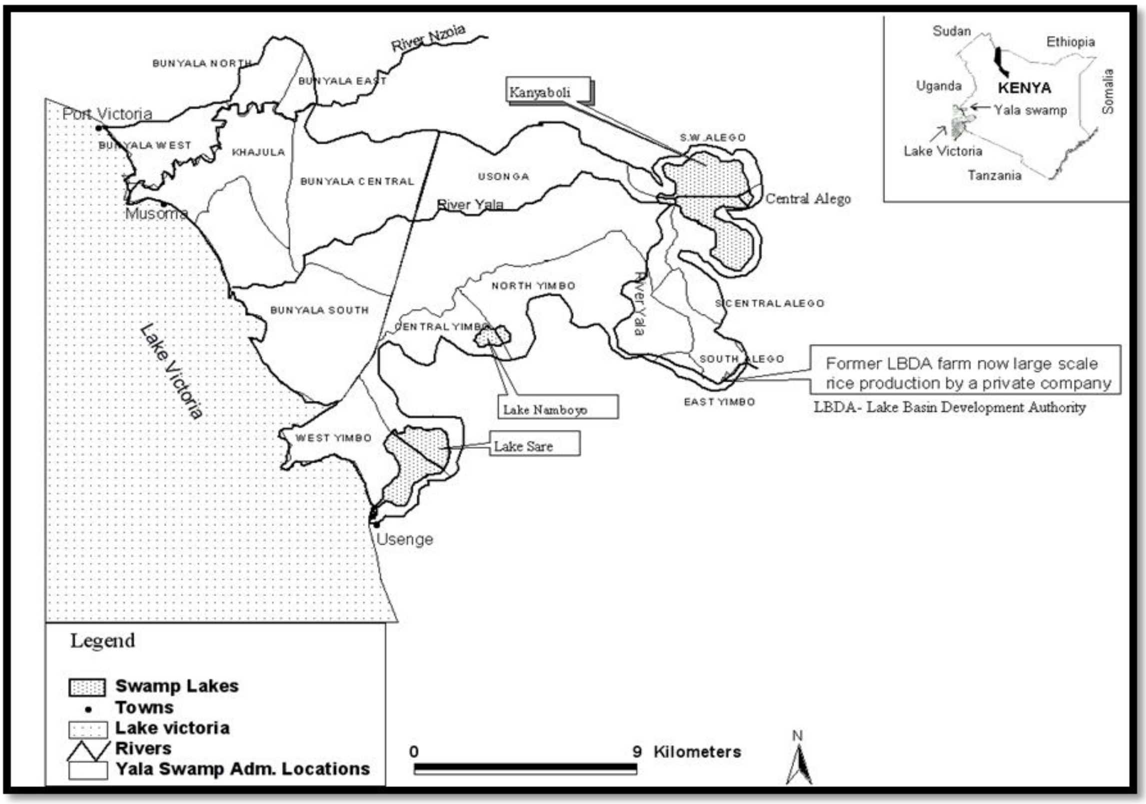

Fig. 1. Yala swamp ecosystem, associated Lakes and administrative Locations (Source: Modified from ICRAF, GIS database, 2004)

2.2. Climate and Hydrological dynamics of Lake Victoria basin

The annual rainfall in LVB forms a bimodal pattern with March to April having long rains while October to November is the period of short rains (Fig. 2). The Yala/ Nzoia catchment has high precipitation in the Northern highland (1,800-2,000 mm per annum) and low in the South-Western lowlands (800-1,500 mm per annum) averaging at about 760mm per annum in Lake Victoria basin.

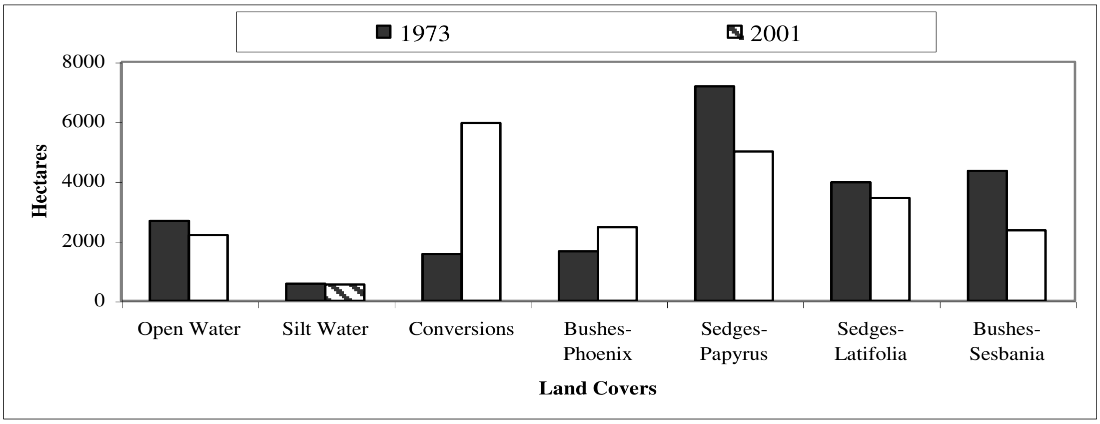

Fig. 2. Land covers dynamics for the 1973 and the 2001*(Source: Lake Victoria Environment Management Programme)*

This high precipitation in the catchment greatly influences the vegetation and ecological dynamics of the wetlands around LVB. However, the rivers in this basin have been experiencing increased discharge over the years due to land cover destruction in the catchment, which has been attributed to both farming and grazing activities (Sangale et al, 2001; Ogello et al, 2013).

2.3. Yala swamp ecosystem historical changes and socio-economic status

Until the mid-1960s the Yala swamp covered a total of 17,500 ha as natural swamp. Several changes has taken place as results of planned alteration, the first change took place with reclamation of 2300 hectares by the Ministry of Agriculture (MOA) in the late 1960s (Envertek Africa, 2015). The second planned reclamation of 6,000 and 9,200 hectares respectively Lake Basin Development Authority (LBDA) did not take place (Envertek Africa, 2015). However some 10,000ha were leased out for reclamation to a private company in 2002, which include the land reclaimed in early 1960s.

Demographic variables exhibit high diversity which high impacts on the wetland ecosystems in LVB. There is high population density approximately 1200 persons per km^2, which is characterised by high rural-urban migration, high poverty and high dependence on the wetlands for their livelihood (GoK, 1994; Hoekstra and Corbett, 1995; Abila, 1998; Gichuki et al., 2001; Ogello et al, 2013; Nasongo et al, 2015). Some of the uses of the wetland include macrophyte harvesting for thatching and basket making, grazing and subsistence farming, which various seasonally depending on flooding pattern (Kareri 1992; Hoekstra and Corbett, 1995; ICRAF, 2000; Mugo and Shikuku, 2000; Nasongo et al, 2015).

4. Materials and methods

4.1. Remote sensing data

In order to compare land cover changes in Yala swamp this study use Multi-spectral scanner (MSS) of 5th February 1973 and Enhanced Thematic Mapper (ETM) of 2nd February 2001. The use of the two images from, allowed temporal and spatial comparative that is often used in land use and cover change analysis (Yadav et al, 2015; Jahagirdar et al, 2016; Rawat and Kumar, 2015). Initially the two images were subjected to relative radiometric corrections and registered to each other. Thereafter in order to facilitate comparison between the two images, the year 2001 image with pixel size of 28.5 m was degraded to 1973 image pixel scale of 57m in ERDAS using the nearest neighbour resampling technique (Lillesand and Kiefer, 1987). This approach is frequently used to facilitate comparison of satellite images with different spatial resolution (Turner et al, 1989; Benson and Mackenzie, 1995; Wu et al, 2002; Saura, 2003).

The satellite image analysis adopted a hybrid classification procedure that combines supervised and unsupervised classification approaches thus increasing effectiveness of the classification (Kloer, 1994). Thereafter, the resulting land cover classes were subjected to post classification analysis. This included accuracy assessment using confusion (error) matrix based on the field observations and land use change matrix analysis to assess land cover transfer. The land covers generated from 2001ETM image were overlaid with the administrative Locations map and the resulting coverage was used to compute spatial data like swamp Location area and accessible area in the swamp.

4.2. Socio-economic survey

The primary data was collected at household level and the survey covered all the 15 administrative units (Locations, see Fig. 1) in the area surrounding the swamp. The exercise yielded a total of 336 questionnaires. Since the focus was on the communities within close proximity to the swamp, the survey was restricted to a distance of 5km from the swamp boundary. The household data collected included household structure, wetland utilization and seasonal utilisation dynamics.

In order to avoid loss of data through interpretation, enumerators from the study area were recruited, trained and used in data collection since they could speak the local language. In the case of swamp-farm size data the measurements given by the farmers were confirmed through a random field visit by the enumerators and the researcher. Secondary data such as swamp administrative Locations coverage was obtained from the World Agro-forestry Centre-ICRAF while 1999 population census and household data was obtained from the Kenya Central Bureau of Statistics.

4.3. Computation of wetland land use indices

By combining population census, household and swamp spatial data using administrative units (Locations) boundary the wetland demographic and land use change indices were computed. The use of administrative units was important since other data like population census are captured at this level. The computed indices were then statistically analysed.

4.3.1. Wetland demographic aspect

The local administrative units (Locations) were used as analysis unit for the statistical analysis between the swamp administrative coverage and the population census data. All the data was aggregated to the respective administrative Location in the swamp including socio-economic data for analysis. The respective swamp spatial coverage per administrative Location less the open water was computed as the swamp accessible area (Access_area) because the open water areas were considered inaccessible for farming purposes. Using the computed accessible swamp area, the proportionate demographic data per the respective swamp Location area were statistically computed. This computation was based on the assumption that there is equal distribution of population and household across the respective Location unit with proportionate use of the swamp. By multiplying the total Location population and household numbers with the percentage of the Location area in the swamp (Access_area) the respective swamp population (New_pop_No) and household numbers (New_hsehold_No) were computed. Then by dividing the respective swamp population (New_pop_No) and household (New_hsehold_No) numbers computed with the Location swamp area (Access_area) the respective swamp population (New_pop_density) and household (New_hsehold_density) densities were computed. These indices represent the proportionate sources of the population and the household's pressure on the swamp utilisation, which were assumed to be directly and indirectly exerting conversion pressure.

4.3.2. Wetland land use data

In order to compute household pressure on the wetland, socio-economic data collected in the field like wetland farming unit held by household was combined with population census and swamp spatial data. This involved computation of several indices as follows. Using the population and the household indices computed above the respective administrative Locations wetland land use data was computed. This approach was used since there was no data available on the swampland distribution per household. Initially, the swamp conversion factor (Conver_Fct) index was computed by taking the average of the wetland land unit held by individual household per Location, which was obtained during the field survey. Using this conversion factor (Conver_Fct) index the household land demand (Hsehold_demand) index was computed. The household land demand (Hsehold_demand) index was computed by multiplying the conversion factor (Conver_Fct) index with the new household number (New_hsehold_No) computed earlier. This index provide for land requirement at the household level based on the wetland utilisation and the 1999 census. This was followed by the computation of the household share (hsehold_share) index, which was calculated by dividing the swamp accessible area (Access_area) with the household demand (Hsehold_demand) for the swampland. This index gave an indication of the population pressure of sharing out the wetland, based on the 1999 population number and the available land.

Thereafter, the percentage in use (Perc_in_use) index was computed as the portion of the mean swampland holding (Conver_Fct) by the households that was under cultivation. Household only cultivated a portion of their swampland holding. The index (Perc_in_use) was computed from the field household data as an indicator of the utilisation level. In order, to get the area under use (Area_underuse) per the respective Locations, the percentage of land under cultivation (Perc_in_use) was multiplied by the household land demand (Hsehold_demand). This gave an indication of the swampland that was under cultivation, against what was available per administrative Location. The computed area under use per Location (Area_underuse) was then divided by the accessible area (Access_area) to give the intensity of wetland utilisation (Use_intsy). The latter index gives the magnitude of the pressure exerted on the wetland as a function of utilisation where this pressure increases with rise of the swamp area under use.

4.4. Co-Validation

This involved two levels. In the first level co-validation was performed by comparing the statistically computed household conversion figures for the whole swamp with the conversions derived from the year 2001 satellite image on land cover analysis. In the second level of co-validation the individual administrative Location level statistically computed households' conversions figures were compared to the conversions spatial values derived from the year 2001 satellite image on land cover analysis.

4.5. Statistical analysis

To find out the interactive significant effect of the explanatory factors on wetland land use change drivers, both the demographic and land use data variables were initially subjected to Pearson correlation analysis. This was followed by stepwise regression analysis to explore the influence exerted by each of the variables in the wetland land use change.

5. Results

5.1. Land cover change detection

The most prominent land cover change is attributed to the conversion of the swamp into farming area. Farming area increased from 1,564 ha in 1973 to 5,939 ha in 2001 (Fig. 2, Table

1). This increase is at the expense of the papyrus-phragmites-typha vegetation community (sedges-papyrus) that decreased from 7,180 ha to 4,999 ha (Fig. 2, Table 1).

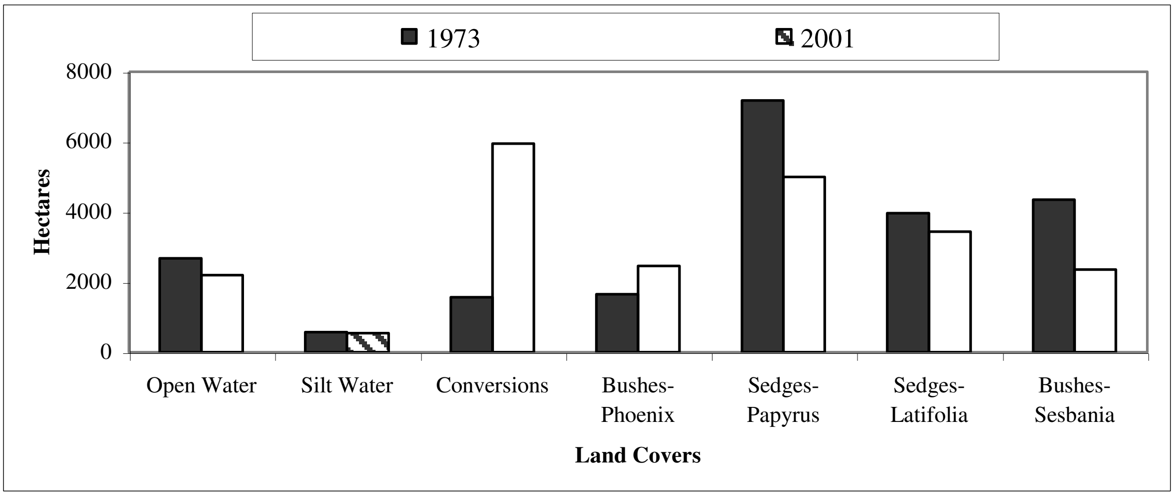

Fig. 2. Land covers dynamics for the 1973 and the 2001

In addition, the latifolia-phragmites community (sedges-latifolia) and the sesbania bushes also decrease over the same period, but the bushes-phoenix community that often appears as coloniser both in the disturbed areas or the less flooded eco-types, show an increase. Likewise, the open water area also decreases due to siltation and vegetation encroachment.

Table 1: Land use change matrix -1973 and 2001 in ha based on 57 m pixel resolution

	Open water	Silt water	Conversions	Bushes-phoenix	Sedges-papyrus	Sedges-latifolia	Bushes-sesbania	Total - 1973
Open water	1,914	305	66	111	160	76	40	2,672
Silt water	3	4	346	25	101	13	78	569
Conversions	9	13	640	136	335	179	252	1,564
Bushes-phoenix	71	59	308	192	625	183	214	1,653
Sedges-papyrus	53	62	1,335	898	1,914	1,871	1,046	7,180
Sedges-latifolia	115	63	542	784	1,256	833	366	3,960
Bushes-sesbania	36	36	2,702	317	609	280	363	4,344
Total - 2001	2,201	543	5,940	2,463	5,000	3,436	2,360	21,942

Comparing the 1973 and the 2001 images, it is noted that most of the land cover changes has occurred along the edge of the swamp and in particular along River Nzoia (Fig. 3, Fig. 4, *A & B*). There is also extensive silt deposition along the Lake Victoria shoreline as well as extension of land to the Lake comparing the 1973 and the 2001 shoreline area (Fig. 3; *see A,* Fig. 4). Further up to the north of River Nzoia the lake gulf, which was prominent in 1973, has almost been cut off from the Lake through a combination of vegetation encroachment into water, silt deposition and human encroachment (*see B*). The presence of water hyacinth *Eichhornia crapssipes* might as well have contributed to the accumulation of silt due to the reduced silt dispersion by water waves especially in the sheltered areas along the shoreline. No such plume is recorded on the mouth of Yala River (see *C)*, which flows through the swamp.

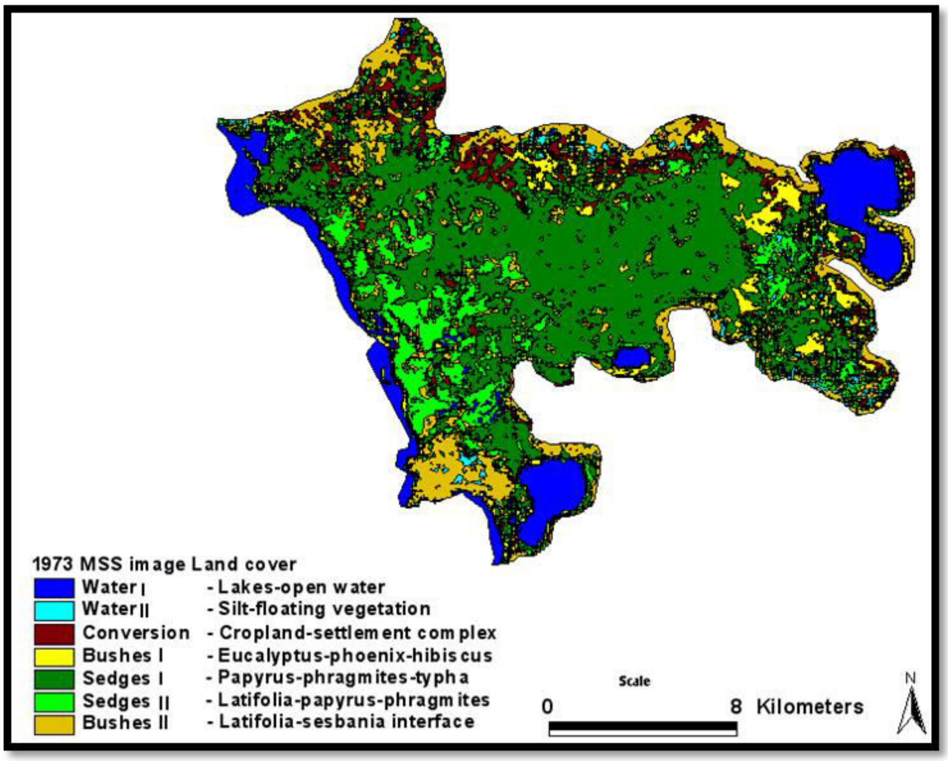

Fig. 3. Land cover classes in 1973 (Image date 5th February 1973)

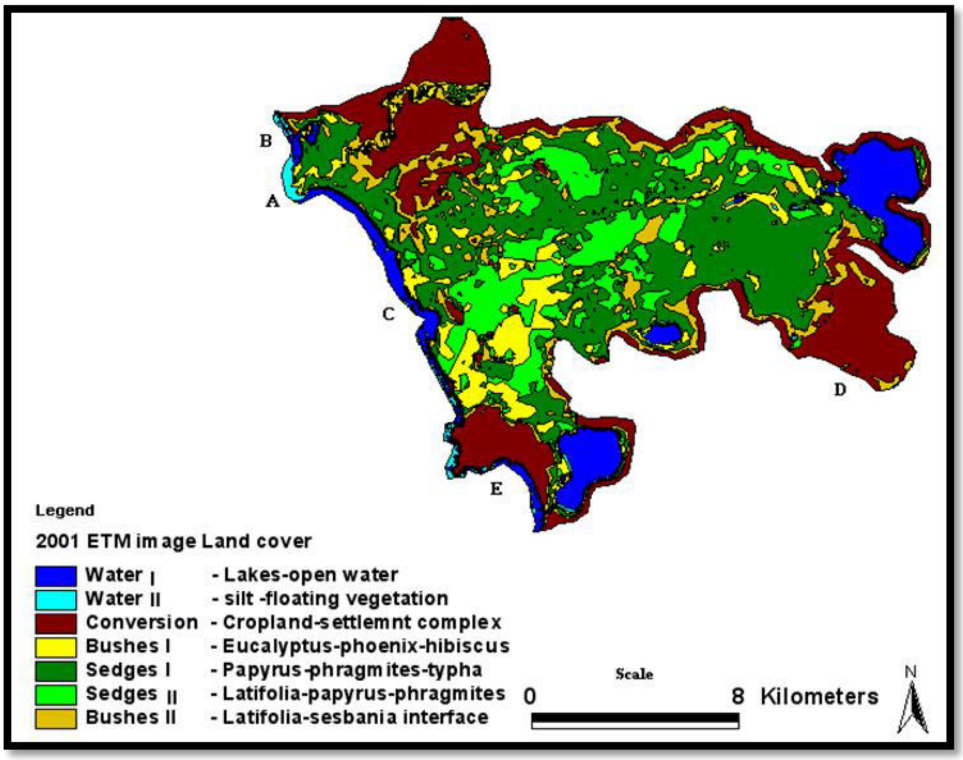

Fig. 4. Land cover classes in 2001 (Image date 2nd February 2001)

Other changes are also noted along the southern section of Lake Kanyaboli (*D*), which are as a result of combined government policy initiatives in the early 1970s to drain this part of the swamp, which was later taken up by small scale farmers in the area. The wetland conversions to farm land on the northwest of Lake Sare area (Fig. 3 and *see E* Fig. 4) are due to the local community initiatives. Again, the administrative locations that has recorded major changes are in the North-western region of the swamp are Bunyala North, Bunyala East, Bunyala West, Khajula, and Bunyala south (Fig. 5 and 6).

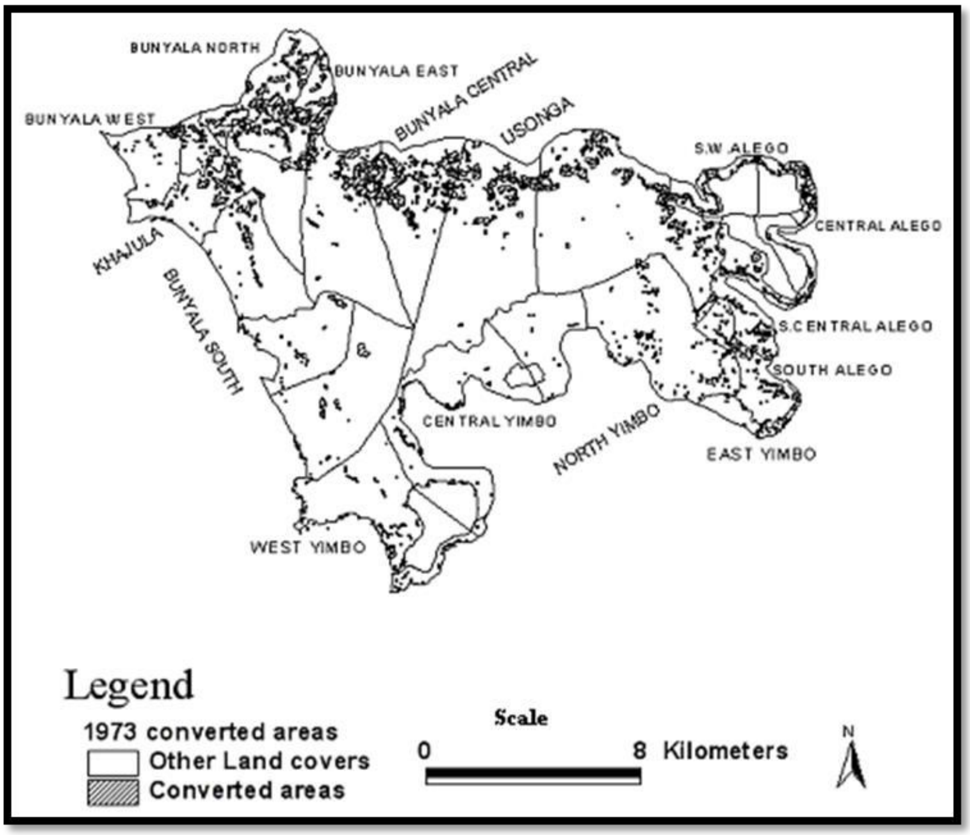

Fig. 5. The areas converted into agricultural land per Location in the 1973

Also noted are significant conversions in administrative Locations around Lake Kanyaboli, in South Central Alego, South Alego, East Yimbo and West Yimbo Locations in the south-western near Lake Sare.

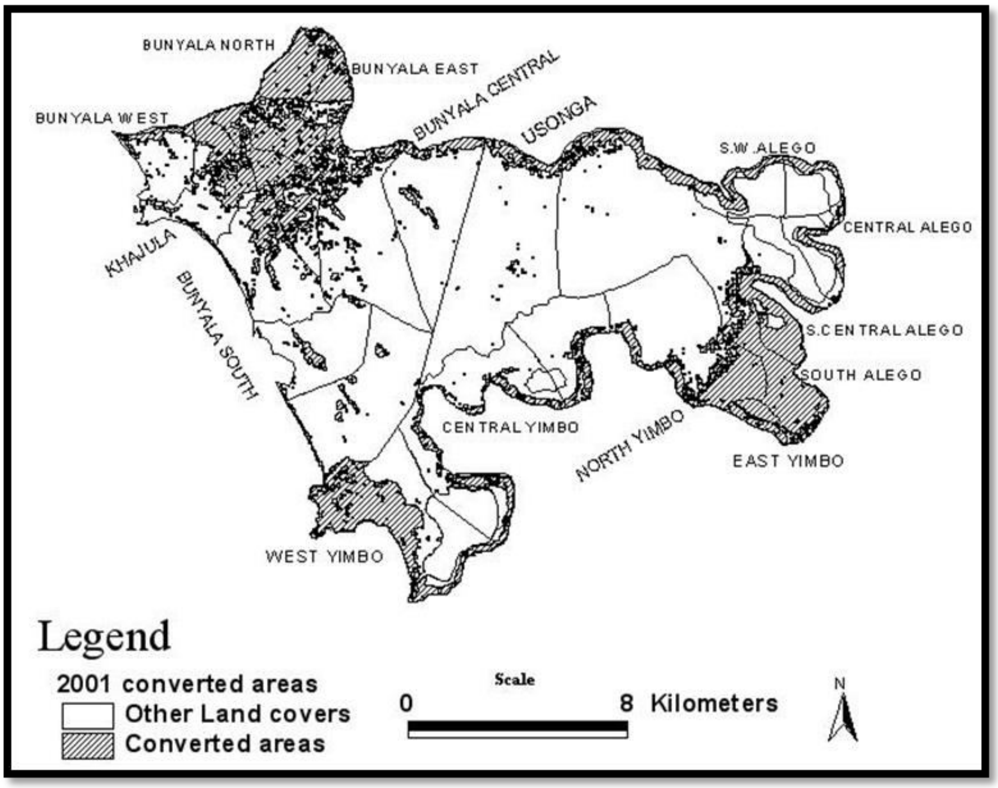

Fig. 6. The areas converted into agricultural land per Location in the year 2001

5.2. Accuracy and classification report

In general, there is high land covers change analysis accuracy assessment with the overall accuracy at 75% and the Kappa statistics being 5% lower, although still high at 70% (Table 2). The classification of the sedges-latifolia (0.94) and silt (0.88) is the most reliable with high overall Kappa statistics. This is followed by bushes-sesbania (0.87) and open water (0.82). This is due to the presence of continuous formations of these land covers. The classification of the sedges-papyrus (0.50) and bushes-phoenix (0.60) had the lowest Kappa statistics.

Table 2: Accuracy assessment report

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy (%)	Users Accuracy (%)	Kappa statistics %
Open water	29	33	28	96.55	84.85	82.31
Silt water	19	9	8	42.11	88.89	87.74
Conversions	31	35	28	90.32	80.00	76.37
Bushes-phoenix	33	36	24	72.73	66.67	60.16
Sedges-papyrus	34	53	31	91.18	58.49	50.09
Sedges-latifolia	29	18	17	58.62	94.44	93.51
Bushes-sesbania	27	18	16	59.26	88.89	87.17
Total	102	202	152			
Overall accuracy				75.25		70.80

The greatest classification errors are noted between sedges-papyrus with bushes-phoenix, sedges latifolia and bushes-sesbania. Sedges-papyrus also records the lowest Kappa statistics at 50%. The low values for sedges-papyrus is due to the ecological intermixing with other macrophytes communities making it hard to separate.

5.3. Socio-economic aspects as determinants of wetland change

In order to understand changes within the study area use of household data was adopted. According to the socio-economic data farming is an important activity, which takes about 95% of the swamp land holdings and contributes more than 70% of domestic food requirements. In addition the declining soil fertility around Yala swamp and the small land holding size in a high population density area generate a high swamp conversion pressure. Land in the wetland is acquired through self-allocation and later passed on through inheritance along kinship lines. This happens because the swamp has no management strategy and is therefore prone to over exploitation through uncontrolled allocation, farming and grazing. On both sides of the swamp, the process of acquiring land is significantly correlated to the nature of land tenure (r= -0.282, at p=0.01; r= -0.179, at p=0.05) and the year of settling in this area (r= -0.290, p=0.01; r= 0.240 p=0.05) respectively. The ownership of the swampland unit has a significant relationship with the nature of land tenure, ($X^2_{(6)}$ 13.40 > 12.59 at p = 0.05). Since the swamp is utilised mainly by the local indigenous people, it is also likely that those with land near the swamp and live nearby throughout the year have a higher likelihood of having land in the swamp. The land around Yala swamp is acquired through inheritance, which emphasis the relationship between swamp utilisation and local land ownership. The negative relationship in the process of acquiring land means that those without land are unlikely to have acquired land in the swamp including the recent settlers. These relationships are weak meaning that other factors are also important in determining ownership of land in the swamp. However, only the household type has a significant relationship with the ownership of land in the wetland $X^2_{(6)}$ 13.40 >12.59 p=0.037 since the process of acquiring land is based at the household rather than at individual level.

There is a gradual rise in the wetland farming with population increase over time, which dates back to the 1920 on both sides of the swamp. The reasons for starting to farm in the wetland are quite varied but almost the same on both sides of the swamp. The most important reason is to supply subsistence food. The other important reasons, which attract people to the wetlands, are water availability, high crop yield and favourable farming climate that constitute 70% in the south and 90% in the north. The need to raise subsistence income through cultivating the wetland is low, constituting only 30% in the south and 10% in the north. This means that farming is mainly geared towards supply of domestic food and therefore the need to raise income is a secondary activity. This kind of farming takes place along the edge of the swamp but gradually edge inwards. In spite of the numerous products that are obtained from the swamp, the community inclination towards farming is quite high. According to the survey, the most prioritised future development is draining the swamp for farming with fishing and conservation taking a low priority. Fishing in the Yala swamp is usually more associated with the open waters of the Lake Victoria and the satellite ones like Lakes Sare, Kanyaboli and Namboyo.

The types of crops grown in the wetland across the seasons on both sides of the swamps include bananas, maize, millet, yams, oil crops (groundnuts, simsim), sugarcane, kales, cowpeas, onions and cassava. There does not seem to be a clear distinction of crops grown in specific season either during the dry or wet season. The annual cycle encompasses three distinct seasons, namely 'long rains' (March to May), 'short rains' (Oct to Nov) and the dry season (Dec to Feb). Actually, cultivation can take place throughout the year because the wetland has a constant supply of water from high rainfall catchments in the upper reaches of Mount Elgon and Chelengani hills although this water is unevenly distributed in the dry season due to topographical limitations in the swamp.

5.4. Wetland demographic indices

Wetland demographic indices such as swamp population density per location are computed by combining the census and the swamp spatial data as presented in (Table 3).

Table 3: Wetland demographic aspects (Computed from 1999 population and household census)

LOCNAME	Loc_total_ area (ha)	Loc_wet_ area %	Loc_wet_ area (ha)	New_pop _No.	New_Pop _density per km^2	New_Hse hold_No.	New_Hse hold_density per km^2
Bunyala Central	3,918	81	3,168	5,052	159	1,342	42
Bunyala East	1,501	16	239	55	23	134	56
Bunyala North	1,225	46	559	2,498	447	571	102
Bunyala South	3,665	93	3,422	4,647	136	1,173	34
Bunyala West	1,363	67	911	8,461	929	2,018	222
Central Alego	652	6	58	247	608	63	156
Khajula	1,838	96	1,757	5,574	317	1,404	80
S. Central Alego	3,324	23	1,242	2,639	341	689	89
S. W. Alego	2,624	15	886	985	252	248	64
South Alego	1,423	42	591	985	167	242	41
Usonga	7,149	76	5,447	5,694	105	1,513	28
Central Yimbo	5,223	23	1,500	1,646	135	384	32
East Yimbo	2,707	8	221	311	141	76	34
North Yimbo	5,503	47	2,629	3,394	130	804	31
West Yimbo	2,995	44	1,655	7,837	591	1,975	149
Total	45,111		22,650	50,011		12,634	

Variable	Explanation
1. Loc_total_area	= Location total area
2. Loc_wet_area %	= Percentage of Location in the wetland area
3. Loc_wet_area	= Location area in the wetland coverage
4. New_pop_No.	= New population number –proportionate number in swamp area
5. New_pop_density	= New population density – based on swamp area per Location
6. New_hsehold_No.	= New household number -proportionate number in swamp area
7. New_hsehold_density	= New household density –based on swamp are per Location

5.5. Wetland land requirements

Based on the demographic indices obtained in (Table 3), the wetland land use data such as the swamp household land demand are computed per location (Table 4).

Table 4: Wetland land use data (Computed from field socio-economic, remote sensing and 1999 census data)

LOCNAME	Conver _Fct (ha)	Access _area (ha)	Hsehold _ demand (ha)	HseHold _share (ha)	Perc_ in_use (%)	Area_ underuse (ha)	Use_intsy (%)
Bunyala Central	2.73	3,168	3,668	0.86	8.54	313	9.89
Bunyala East	2.62	239	351	0.68	20.00	70	29.38
Bunyala North	2.62	559	1,495	0.37	20.00	299	53.48
Bunyala South	2.49	3,422	2,917	1.17	27.32	797	23.29
Bunyala West	2.62	911	5,287	0.17	11.70	619	67.93
Central Alego	1.15	41	104	0.39	23.91	25	61.55
Khajula	2.59	1,757	3,636	0.48	18.09	657	37.41
S. C. Alego	2.70	775	2,981	0.26	20.37	607	78.38
S. W. Alego	1.8	391	1,013	0.39	20.21	205	52.40
South Alego	2.85	591	688	0.86	52.63	362	61.35
Usonga	4.29	5,432	6,508	0.83	13.53	881	16.22
Central Yimbo	1.96	1,216	927	1.31	68.06	631	51.92
East Yimbo	1.90	221	145	1.53	56.25	81	36.75
North Yimbo	2.02	2,602	1,637	1.59	74.47	1,219	46.86
West Yimbo	2.00	1,327	4,929	0.27	100.00	4,929	371.52
Summation		22,651	36,287			11,696	

Variable	Explanation
1. Conver_Fct	= Conversion factor - average swamp unit held per household
2. Access_area	= Accessible area - swamp area less water
3. Hsehold_demand	= Household demand - function of conver-fct and new population
4. Hsehold_share	= Household share - unit per household based on 1999 census
5. Perc_in_use	= Percentage in use - portion of the unit held that is in use
6. Area_underuse	= Area under use - coverage under use in the swamp
7. Use_intsy	= Use intensity - utlisation intensity of the swamp land

From the calculated statistics on land demand in the swamp (Table 4), the average conversion factor (Conver_Fct) is 2.4 (ha) ± s.e 0.163, some households have smaller units while others have bigger units than this average. Using the average for the respective administrative locations, the total household land demand (hsehold_demand) is 36,286.63 ha against accessible area (Access_area) of 22,650.07 ha. This implies that since the computed demand is higher than what is available, wetland conversion to farm land pressure is bound to increase with time. However, it is important to note that not all households are simultaneously engaged in farming in the wetland as implied by the calculation, since some land holdings in the wetlands are idle. Furthermore, households cultivate only a part of what they lay claim to, which is given by the summation of the percentage of land under use (perc_in_use) 11,696 ha, which is 50% of the accessible land. Again, due to the temporal variation in the use of the swamp by the households, the 11, 696 ha that is perc_in_use are not all simultaneously in use at the same time. This means that the total area under use at any particular time is less than this figure. Therefore, the high hsehold_demand (36,286.63 ha) gives an indication of the pressure that is likely to be exerted in the near future. This pressure will result in the opening up of additional wetland area as the household number increases and as the relative proportion of the farming household community in the wetland goes up.

5.6. Wetland land use change drivers statistical analysis

Correlations

The land use correlations are done using the population indices as explanatory factor and the swamp use indices as the response factor in SPSS (Table 5). In general, the correlations are relatively high. The household share has a negative relationship with both the household density (r = -0.75) and population density (r = -0.69). This means that a rise in both of these demographic variables would result in a decrease of the swampland shareholding as demand for farming land increases (Table 5).

Table 5: Wetland land use change drivers correlations values

	New _hsehold density	NEW _POP -density
Dependent - Y	Independent - X	
Conver_fct	-0.16	-0.17
Hsehold_demand	0.28	0.32
Hse_hold share	-0.75*	-0.69*
Perc_in_use	-0.10	-0.06
Area_underuse	0.28	0.28
Use_intsy	0.46	0.44

Pearson correlation –
*sign. at the 0.01 level (2-tailed)

Although the "conver_fct" and the "perc_in_use" do not record significant relationship, they have a negative relationship with both the population and household densities. This means that as both densities increase the land unit under conversion and utilisation will tend to decrease exerting more pressure on the swamp.

Regression analysis

The coefficients of determination of the four drivers are significantly high especially in the household densities, the total and new population (Table 6). The household density (r = 0.555) is important in determining shareholding, since wetland land holdings are based at the household level and not at individuals levels. According to this relationship an increase in household density would result in decrease of the corresponding shareholding $y = 1.216 - 0.01x$, *where* x= *density*. The area under land use and the utilisation intensification are significantly influenced by the location population number. This means that an increase of the local population is bound to increase the overall area under use while reducing shareholding at the same time as more people move into the swamp. However, since the swamp land size does not change this will gradually lead to swamp utilisation intensification.

Table 6: Coefficient of determination and R^2 for selected wetland change drivers

Dependent-Y	New_hsehold_density	New_pop_density	Access_area	*** loc_total_pop	New_pop_No.	R^2 value
	Independent Var-X					
Conver_fct	0.07	0.02	**0.00** (0.03)	-0.09	0.14	0.30
Hsehold_demand	-0.14	-0.16	**0.36** (0.03)	0.02	**0.68** (0.00)	0.89 / 0.84
Hsehold_share	**-0.01** (0.001)	0.75	0.01	-0.01	0.02	0.56
Area_underuse	-0.20	-0.28	0.06	**0.21** (0.001)	0.03	0.59
Use_intsy	0.07	-0.003	-0.28	**0.02** (0.002)	0.32	0.55

Sign. value of coefficients indicated in parenthesis for the relevant predictors

While the swamp conversion and household demand are dependent on the availability of land, that is the coverage per Location (r^2 = 0.30, r^2 = 0.36) (Table 6), the household demand is determined by two factors, which include 1) accessibility and 2) swamp computed population numbers. The conversion of the swamp is dependent on land availability, population numbers and indirectly by household densities.

5.7. Spatial wetland modifications model

The household variable is important in determining the overall conversion, since the households rather than individuals acquires land in the swamp and make the decision for farming. The population increase per Location does not necessary translate to an equal increase of the household numbers. On the contrary, it acts as source of households demand to acquire extra farming land and as source of utilisation intensification pressure. This extra acquisition depends on land availability. Therefore, those sections of the swamp with large spatial coverage are likely to have higher demand resulting in more conversions compared to areas that have relatively small coverage. While the later are likely to experience utilisation intensification. The source of this pressure emanates from the people attracted to the land, since land availability is the limiting factor. This is clearly illustrated in Fig. 7, which shows the relationship between household demand for land in the swamp and population variables.

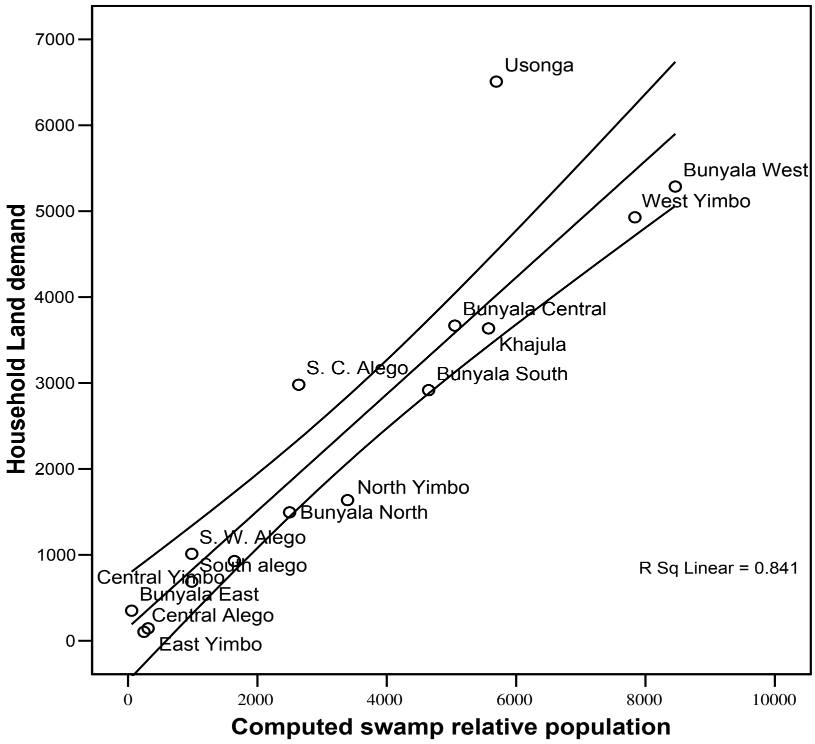

Fig. 7. Relationship between household demand and computed swamp relative population

The relationship of household demand and computed swamp relative population is likely to be compounded by the household shareholding as the household density increases. That is as the households density increases wetland share unit decreases (r= - 0.75, *y = 1.216-0.01x, where x= density)* thereby increasing intensification. Similarly, utilisation intensification increases rapidly as the population increase, *y = -36.04 +0.02x, where x is Location population*. To compute the swamp anthropogenic land use change factor the total accessible area and the household per Location are first converted into percentages. These factors are used since they came out prominently as being important in determining land use change in the Yala swamp. The second step is to take the average of the two percentages per location so as to have one indicative figure of the conversions (Fig 8). The Locations with high conversion indices are located in the north as well as in areas with large spatial coverage. These include, Bunyala south, Bunyala central, Usonga and partly West Yimbo (Fig 8). This outcome relates very well with the relationship between household demand and population (Fig. 7), with areas having high conversion indices also having high household demand.

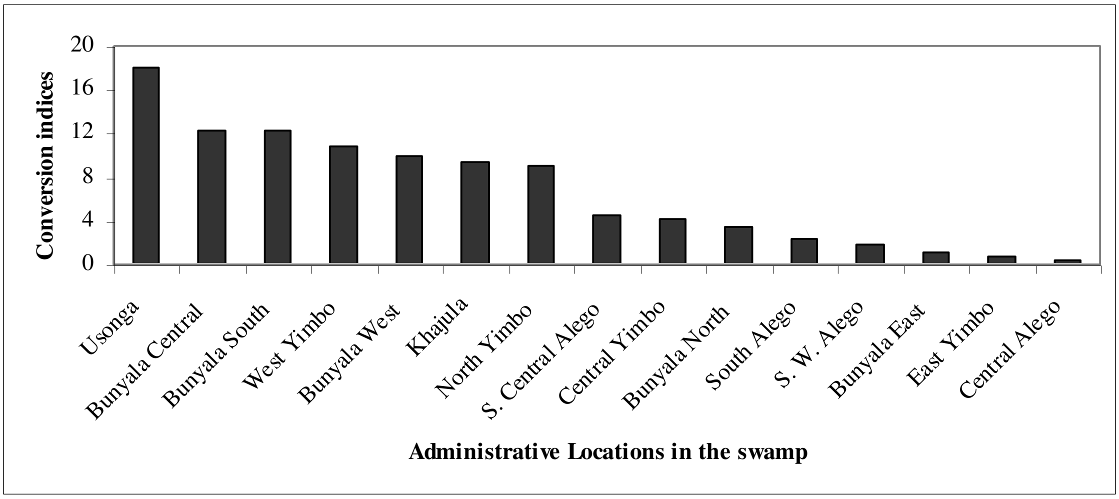

Fig. 8. Land use conversion indices per Location

The impact of leasing out of accessible wetland to a large-scale farming company on the eastern side of the swamp near Lake Kanyaboli is likely to alter the conversion pattern. The pressure of the displaced small-scale farmers is not likely to be distributed equally to the whole swamp from the statistical calculation, there is a clear relationship between population and demand for swamp farming land (*$y = -36.04 + 0.02x$, where x is Location population)*. Thus, the administrative Locations of Central Alego, South Central Alego and North Yimbo that are near the large-scale farm are likely to receive the displaced swamp conversion pressure resulting in more conversions in the wetland or intensified cultivation.

5.8. Co-Validation

In order to assess the significance and the validity of the household land use coverage values in the swamp generated from socio-economic and demographic data, these results are compared with the land use and cover values derived from the 2001 satellite imagery. The land cover classes of the wetland are generated from the satellite image independent of the household-census wetland land demand computation. The spatial data from the 2001 Landsat image indicate the total direct-converted area at 5,939.84 ha against a total household computed coverage of 11,696 ha for the whole swamp ecosystem. The difference is attributed to the difference in time of acquiring the 2001 satellite image and the farmers seasonal conversions of the swamp. Because the swamp conversions are both seasonal and temporal this difference between household computed and land cover derived values can be compensated by examining 2001 satellite image land cover classes. Two of the land cover classes from among the seven 2001 imagery derived land cover classes are likely to be converted seasonally for farming or prolonged farming period. This is based on the field information and the vegetation composition. These land cover classes are the bushes-sesbania community and the sedges-latifolia community (Fig. 4), which covers 2,359.96 ha and 3,435.64 ha respectively (Table 1), which gives a total area of 11,735.44 ha. The two land cover classes forms an interface between the papyrus community and the dry eco-type both of which are often used for farming. These land cover classes fall within the northern side, south of the large conversions along River Nzoia and north of Lake Kanyaboli (Fig. 4, Fig. 6). In addition, these areas falls within the Locations, which have also relatively high conversion indices. The statistically household computed figures

11,696 ha are within a range of >90% of 2001 satellite imagery derived values at 11,735.44 ha, which validates the statistical calculations approach and in default the landuse changes drivers in the Yala swamp.

6.1. Discussion

According to Bičík et al (2015) 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 (Merten et al, 2000, Ampofo, 2015). Other experiences can also be drawn from rangelands (Serneels and Lambin, 2001) and studies on human impact in wetlands (Mugisha, 2002; Githaiga et al, 2003). Use of interdisciplinary approach allows great understanding of the interaction between socio-economic and land use and covers changes (Rindfuss et al, 2004; Bičík et al 2015). This approach was adopted in the Yala swamp study. In the Yala swamp, several factors, which are largely demographic in nature are responsible for driving land-cover changes. From the household data analysis, cultivation in the swamp was identified as the most significant proximate driver of land-cover change. The main aim of farming in the wetland is to supply domestic food and raise subsistence income. In addition, other local drivers of land cover changes include grazing, mining of clay for brick making and macrophytes harvesting. The drive for cultivation in the swamp emanate demand created by high household and population densities, reducing land acreage and low soil fertility.

According to Lambin et al, (2001); Miyamoto et al, (2014); Bičík et al (2015) demand for food is among agricultural activities that constitute major driver for land cover change. In Africa, subsistence agriculture is a major factor. While in Latin America and Asia pasture and commercial logging are major drivers (Geist and Lambin, 2002). In lake Victoria basin wetland uses especially is dominated by cultivation (Turyahabwe et al, 2013; Ogello et al, 2013). Use of wetland for cultivation has been noted in other areas like India, which contributes to land cover change (Govindaprasad and Manikandan, 2014). It is however noted that other major drivers housing have little effect in Yala swamp because the annual floods do not allow permanent settlement.

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 (Miyamoto, 2013; Govindaprasad and Manikandan, 2014; Manh Vu et al, 2014). In Yala swamp, the area along river Nzoi 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 constrain in low population density areas.

It is noted that two other factors though not strongly related and directly linked to land conversion act as underlying factors. The two are transport network that assist in movement of farming products along river Nzoia part of the wetland to other nearby markets. The second factor is the presence of agrarian community on this side the Luhyas compared to the agro-pastoralists the Luos in the southern side. Thus, the frequent and high flood occurrence does not deter the Luhyas from farming in the area when water recedes because floods bring fertile soils each season. This outcome supports the argument that land availability and physical infrastructures act as underlying drivers of land cover change (Polyakov and Zhang, 2008; Manh Vu et al, 2014; Govindaprasad and Manikandan, 2014; Bičík et al 2015; Rawat and Kumar 2015). Similarly, in Cameroon, the proximate of road infrastructure was directly linked to deforestation (Mertens and Lambin, 2000).

Land use changes are characterised by high dynamics that create diverse heterogeneity in agricultural land that limit predictability using statistics like regression analysis for projections. Introduction of new land use dimensions like mechanisation triggers new land cover change dynamics like mechanisation in Southern, Kenya (Serneels and Lambin, 2001) and marketing oriented farming in Southern Cameroon (Mertens and Lambin, 2000) and seed production farm in Yala swamp (Gok, 1994; Aloo, 2003; Ogello et al 2013; Envertek Africa 2015). These dynamics often increase population density supplying labour for land cover change. In the case of Yala seed production area, leasing of this portion for large scale farming introduces new dynamics in land cover change and distorted the indigenous community low technology gradual household pressure on the wetland. The effect of wetland utilisation intensification will be felt most in administrative units bordering this area like North Yimbo mainly emanating from small scale farming to supply food to large scale farm works. Income from the large scale farm is likely to be devoted to purchase of food along with other household demands like education and health. Noting that drivers form complex web of interactions, the effect of this emerging scenario and how it shapes land use and cover change is currently not clearly understood. According to Bičík et al (2015) development of market driven farming can change drivers of land cover change significantly. Other drivers of land use and cover changes could be triggered by change in legislations, economic and climate change. For example, according to Merten et al (2000), IMF structural adjustments programmes in early 1990s triggered accelerated deforestation in Cameroon.

It is noted that increase of subsistence agriculture in Yala swamp is due to high population density which creates demand for farming area in a low economic prospects that limits alternative livelihood options. This compares well with studies in Honduras, where lack of alternative economic possibilities lead to proportionate increase of farming area with population increase (Kok, 2004). The area around Yala swamp is characterised by unreliable rainfall average 760mm per annum, which is inadequate for rainfed farming meaning that the swamp provides an ideal alternative towards food production. Emergency of economic activities like the large scale farming in the area is likely to attract more people thus changing the demographic dynamics such as increase in population driving up demand for farming in the wetland. The true impact of this scenario will need monitoring to capture the emerging large scale farming associated demographic scenarios. At the moment such argument as like market driven land use change as advanced by von Thuenen indicated weak influence as, market influence is shadowed by subsistence farming and poor road status, dry weather roads.

Comparing the derived land use and cover changes data from the satellite imagery are within 50% of the household computed data, indicating the high validity of the statistical computation when approached from Yala swamp as a whole. However, this does not hold at administrative units due to high spatial variability meaning that more household data would be required on conversation rates to enable predicting conversion at administrative Location level

Yala swamp lack a management plan and with disjointed and low initiative in conservation locally the current wetland conversion to cultivated land are predictably bound to continue increasing. The issue of lack of management strategy has been cited before (Ogello et al, 2013). At the moment farming land demand is based on demographic variables like increase in population and household densities and overall more swamp conversion will take over time as population increase. Other variables like improvement in road networks are crucial in determining land demand and overall conversions in the Yala swamp.

6.2. Conclusion

The drivers of land cover change in the Yala swamp are numerous although the need to meeting domestic food and meet livelihood aspects like income are more significant. The use of statistical model allows us to uncover the source of pressure to convert the swamps, which are mainly demographic variables, population and household densities. However, using this approach we are not able to locate specific area of change but rather we can predict new conversion especially from low flooding zones. However, we cannot predict specific time of change and magnitude as change as this is compounded by other variables like infrastructural change and economic growth dynamics.

This raises the question of scale in co-validation. By comparing the remote sensed value and socio-economic value of the whole ecosystem this work well but at lower sale of administrative location, our ability to predict conversion is limited by other variables at this lower spatial scale. According to Miyamoto (2013), among variables that complicate spatial variables in land cover change include policy change and infrastructure development since they operate as underlying drivers to proximate land activity. At the moment road infrastructure limits transportation of farm products but improved like upgrading to bitumen standard would increase market access and thus more demand for farming area. With the current inadequate infrastructures in the swamp area, this limits wetland utilisation and the low income levels also limit land cover change in terms of adoption of high technology for land use by the indigenous community. In conclusion, a policy on conservation on the sustainable management of the wetland may contribute to lower rate of wetland conversions and possible restoration as well as change the path and magnitude of the current drivers.

References

Ampofo, S., Ampadu, B., & Abanyie, S.K. (2015). Landcover Change Patterns in the Volta Gorge Area, Ghana: Interpretations from Satellite Imagery. Journal of Natural Sciences Research, Vol.5 (4), 2224-3186 (Paper), 2225-0921 (Online).

Abila, R. (1998). Utilisation and economic valuation of the Yala swamp wetland, Kenya. In: Gawler, M. (Ed.), Strategies for wise use of wetlands: best practices in participatory management, Proceedings of 2nd International Conference on Wetlands and Development, (November 1998, Dakar, Senegal). Wetlands International IUCN, WWF Publications No. 56, Wageningen, The Netherlands.

Aloo, P. A. (2003). Biological diversity of the Yala swamp lakes, with special emphasis on fish species composition, in relation to changes in the Lake Victoria Basin (Kenya): threats and conservation measures. Biodiversity and Conservation 12, 905–920.

Asselen, S. V., Verburg, P. H., Vermaat, J.E., & Janse, J.H. (2013) Drivers of Wetland Conversion: a Global Meta-Analysis. Drivers of Wetland Conversion: a Global Meta-Analysis. PLoS ONE 8(11), 81292-10.1371.

Benson, B. J., & Mackenzie, M. D. (1995). Effects of sensor spatial resolution on landscape structure parameters. Landscape Ecology 10, 13-120.

Bičík, I., Kupková, L., Jeleček, L., Kabrda, J., Štych, P., Janoušek, Z., & Winklerová, J. (2015). Land Use Changes in the Czech Republic 1845–2010 : Socio-Economic Driving Forces. Springer Geography (ISSN 2194-315X), 9783319176703; 9783319176710.

Binswanger, H. P., & McIntire, J. (1987). Behaviour and material determinants of production relations in land abundant tropical agriculture. Economic Development and Cultural Change 36, 73-99.

Boserup, E. (1965). The conditions of agricultural growth. The economics of agrarian change under population pressure (pp. 18-34). London, Earthscan Publications Ltd.

Brown, L. R. (1994). Full house: reassessing the earth's population carrying capacity. W. W. Norton, New York.

Daniels, A. E., & Cumming, G.S. (2008). Conversion or Conservation? Understanding Wetland Change in Northwest Costa Rica. Ecological Applications. Volume 18(1), 1–281.

Envertek Africa Consult Limited, (2015). Proposed sugarcane plantation and processing mill for dominion farms limited in Siaya county location: reclaimed section of Yala swamp on longitude 34.171380 east and latitude 0.022992 north in the flood plain of river Yala in Siaya and Bondo sub-counties in Siaya county, Kenya. Environmental and social impact assessment (esia) study report. Dominion farms limited (dfl)

Geist, H. M., & Lambin, E. F. (2002). Proximate causes and underlying driving forces of tropical deforestation. BioScience 52 (2), 143-150.

Gichuki, J., Guebas, F. D., Mugo, J., Rabuor, C. O., Triest, L., & Dehairs, F. (2001). Species inventory and the local uses of the plants and fishes of the Lower Sondu Miriu wetland of Lake Victoria, Kenya. Hydrobiologia 458, 99–106.

Githaiga, J. M., Reid, R., Muchiru, A., & van Dijk. S. (2003). Survey of water quality changes with land use type, in the Loitokitok Area, Kajiado District, Kenya. Land Use Change Impacts and Dynamics (LUCID) Project Working Paper 35, Nairobi, Kenya: International Livestock Research Institute.

Government of Kenya, (1994). District development plan; Siaya District. Government Printers, Nairobi.

Govindaprasad, P. K., & Manikandan, K. (2014). Agricultural Land Conversion and Food Security: A Thematic Analysis. International Research Journal of Agriculture and Rural Development. Issn, Vol.3.No.1, 2319-331x.

Green, G. M., & Sussman, R. W. (1990). Deforestation history of the eastern rain forest of Madagascar from satellite images. Science 2, 212-215.

Hardin, G. (1968). The tragedy of the commons. Science 162, 1243 – 1248.

Hoekstra, D., & Corbett, J. (1995). Sustainable agricultural growth for highlands of east and central Africa: prospects to 2020. Paper presented at the EcoRegions of the developing world: a lens for assessing food, agriculture and the environment to the year 2020. In ICRAF, 2000. Improved land management in the Lake Victoria basin: linking land and lake, research and extension, catchment and Lake Basin. First Technical Report, Start-up Phase, July 1999 to June 2000, ICRAF and Ministry of Agriculture and Rural Development.

Hollis, G. E. (1990). Environmental impact of development on wetlands in arid and semi-arid lands. In: Wetlands and Integrated River Basin Management. Experiences in Asia and the Pacific. United Nations Environment Programme, Nairobi.

Huigen, M. G. A. (2004). First principles of the Mameluke multi-actor modelling framework for land use change, illustrated with a Philippine case study. Environmental Management 72, 5-21.

ICRAF. (2000). Improved land management in the Lake Victoria Basin: linking land and lake, research and extension, catchment and Lake Basin. First Technical Report, Start-up Phase, July 1999 to June 2000. ICRAF and Ministry of Agriculture and Rural Development.

Jahagirdar, A., Patil, M., Pawar, V., & Kharat, V., (2016). Comparative Study of Satellite Image Edge Detection Techniques. International Journal of Innovative Research in Computer and Communication Engineering (Vol. 4, Issue 5, 2320-9801.

Johnson, T. C., Kelts, K., & Odada, E. (2000). The holocene history of Lake Victoria. AMBIO: A Journal of the Human Environment 29 (1), 2-11.

Jones, J. R. (1998). Colonization in Central America. In: Kok, K., (2004). The role of population in understanding Honduran land use patterns. Journal of Environmental Management 72, 73-89.

Kairu, J. K. (2001). Wetland Use and Impact on Lake Victoria, Kenya Region. Lakes and Reservoirs. Research and Management 6, 117 - 125.

Kareri, R. W. (1992). The sociological and economic values of Kenya's wetlands. In Crafter, S. A., Njuguna, S. G and Howard, G. W (Eds) 1992, Wetlands of Kenya, Proceedings of the Kenya Wetlands Working Group Seminar on Wetlands of Kenya, National Museums of Kenya, Nairobi, Kenya 3-5 July 1991. Vii + 183pp.

Kloer, B. R. (1994). Hybrid parametric/non-parametric image classification. Paper Presented at the ACSM-ASPRS Annual Convention, Reno, Nevada.

Kok, K., Farrow, A., Veldkamp, A., & Verburg, P. H. (2001). A method and application of multi-scale validation in spatial land use models. In: Serneels, S., Lambin, E. F., 2001. Proximate causes of land-use change in Narok district, Kenya: a spatial statistical model. Agriculture, Ecosystem and Environment 85, 65-81.

Kok, K. (2004). The role of population in understanding Honduran land use patterns. Journal of Environmental Management 72, 73-89.

Kwast, J. (2002). Land cover classification and DEM generation. Using SPOT and Landsat images in the Lake Victoria basin, Western Kenya.

Lambin, E.F., Turner II, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., Coomes, O. T., Dirzo, R., Fischer, G., Folke, C., George, P. S., Homewood, K., Imbernon, J., Leemans, R., Xi, Li., Moran, E. F., Mortimore, M., Ramakrishnan, P. S., Richards, J. F., Skanes, H., Steffen, W., Stone, G. D., Svedin, U., Veldkamp, T. A., Vogel, C., & Xu, J. (2001). The causes of land-use and land-cover change: moving beyond the myths. In: McConnell, W. J., Sweeney, S. P., Mulley, B., 2004. Physical and social access to land: spatio-temporal patterns of agricultural expansion in Madagascar. Agriculture, Ecosystems and Environment 101, 171-184.

Lehnera, B., & Do¨lla, P. (2004).1Development and validation of a global database of lakes, reservoirs and wetlands. Journal of Hydrology 296, 1–22

Lillesand, T. M., & Kiefer, R. W. (1987). Remote sensing image interpretation. 2nd Edition. John Wiley, Chichester and New York.

Luan, Z., & Zhou, D. 2013. Impacts of Intensified Agriculture Developments on Marsh Wetlands. The Scientific World Journal. Volume 2013 (2013), Article ID 409439, 10 pages.

Manh, Vua, Q., Lea, BQ., Frossardd, E., & Vlek, P. L. G., (2014). Socio-economic and biophysical determinants of land degradation in Vietnam: An integrated causal analysis at the national level / Land Use Policy 36, 605–617

Melton1, J. R., Wania, R., Hodson, E. L., Poulter, B., Ringeval, B., Spahni, R., Bohn, T., Avis, C. A., Beerling, J., Chen, G., Eliseev, A. V., Denisov, S. N., Hopcroft, P. O., Lettenmaier, D. P., Riley, W. J., Singarayer, J. S., Subin, Z.M., Tian, H., Zurcher, S., Brovkin, V., van Bodegom, P. M., Kleinen, T., Yu, Z. C., & Kaplan, J. O. (2013). Present state of global wetland extent and wetland methane modelling: conclusions from a model inter-comparison project (WETCHIMP). Biogeosciences, 10, 753–788

Mertens, B., & Lambin, E. F. (2000). Land-cover changes trajectory in southern cameroon. Annals of the association of american geographers 90(3), 467 – 494.

Mertens, B., Sunderlin, W. D., Ndoye, O., & Lambin, E. F. (2000). Impact of macroeconomic change on deforestation in South Cameroon: integration of household survey and remotely-sensed data. World Development 28 (6), 983-999.

Mugisha, S. (2002). Root causes of land cover/use change in Uganda: An account of the past 100 years. Land Use Change Impacts and Dynamics (LUCID) Project Working Paper 14; Nairobi, Kenya: International Livestock Research Institute.

Mugo, F. W., & Shikuku, O., (2000). Improved land management in the Lake Victoria Basin: linking land & lake, research and extension, catchment and Lake Basin. Natural resources use, constrains and possible intervention. The case for Ombaka Wetlands Focal Area in Nyando District. World Agroforestry Centre-ICRAF, Nairobi.

Miyamoto, M., Parid, M. M., Aini, Z. N., & Michinaka, T. (2014). Proximate and underlying causes of forest cover change in Peninsular Malaysia. Forest Policy and Economics**.** Volume 44, Pp 18–25.

Mwita, E., Menz, G., Misana, S., & Nienkemper, P. (2012). Detection of Small Wetlands with Multi Sensor Data in East Africa. Journal of Advances in Remote Sensing, 1, 64-73.

Narumalani, S., Rundquist, D. C., Maeder, J., & Payton, S. (1999). Characterizing patterns and trends of wetland vegetation using the Normalized Difference Vegetation Index (NDVI). Centre for Advanced Land Management Information Technologies (CALMIT), University of Nebraska, USA.

Nasongo, A. A. S., Zaal, F., Dietz, T., & Okeyo-Owuor, J. B. (2015).Institutional Pluralism, access and use of wetland resources in Nyando papyrus, Kenya. Journal of Ecology and the natural Environment. Vol 7(3), 56-71.

Njiru, M., Waithaka, E., Muchiri, M., van Knaap, M., & Cowx, I. G. (2005). Management of Lake Victoria fisheries Exotic introductions to the fishery of Lake Victoria: What are the management options? Lakes & Reservoirs: Research and Management 2005 10, 147–155.

Turyahabwe, N., Kakuru, W., Tweheyo, N., & Tumusiime, D. M. (2013). Contribution of wetland resources to household food security in Uganda. Agriculture & Food Security, 2:5.

OECD, (1996). Guidelines for aid agencies for improved conservationand sustainable use of tropical and sub-tropical wetlands, Tech. rep., Organization for Economic Co-operation and Development, Paris, France.

Ogello, E. O., Obiero, K., & Munguti, J. M. (2013). Lake Victoria and the Common Property Debate: Is the Tragedy of the Commons a Threat to its Future? Lakes, Reservoirs and Ponds, Vol. 7(2), 101-126,

Otieno, M. N., Odenyo, V. O. A., & Okeyo, J. B. (2001). The capabilities of multispectral Landsat TM for mapping spatial landscape characteristics of a tropical wetland. The case of Yala swamp, Kenya. In proceedings of LVEMP, First Regional Scientific Conference 3rd-7th December 2001, Kisumu, Kenya.

Pender, J., (1998). Population growth, agricultural intensification, induced innovation and natural resource sustainability: An application of neoclassical growth theory. Agricultural Economics 19, 99-112.

Pingali, P., Bigot, T., & Binswanger, P. H. (1987). Agricultural mechanisation and the evolution of farming systems in Sub-Saharan Africa (pp. 216). Baltimore, MD, USA: The John Hopkins University Press. (A World Bank publication).

Polyakov, M., & Daowei, D. (2008). Population Growth and Land Use Dynamics along Urban–Rural Gradient Maksym. Journal of Agricultural and Applied Economics, 40,2, 649–666.

Rawat, J. S., & Kumar, M. (2015). Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India. The Egyptian Journal of Remote Sensing and Space Science. Volume 18, Issue 1, 77–84.

Reid, R. S., Gachimbi, L. N., Worden, J., Wangui, E. E., Mathai, S., Mugatha, S. M., Campbell, D. J., Maitima, J. M., Butt, B., Gichohi, H., & Ogol, E., (2004). Linkages between changes in land use, biodiversity and land degradation in the Loitokitok Area of Kenya. Land Use Change Impacts and Dynamics (LUCID) Project Working Paper 49 Nairobi, Kenya: International Livestock Research Institute.

Rindfuss, R. R., Stephen, J., Walsh, S. J., Turner II, B. L., Fox, J., &Mishra, V. (2004). Developing a science of land change: Challenges and methodological issues. Proceedings of the National Academy of Sciences 101 (39), 13976–13981.

Rudel, T. K., & Roper, J. (1996). Regional patterns and historical trends in tropical deforestation, 1976-1990: a qualitative comparative analysis. Ambio 27 (4), 160-166.

Ruthenberg, H. (1976). Farming systems in the tropics, 2nd ed. Oxford, England: Oxford University Press.

Sangale, F., Okungu, J., & Opango, P. (2001). Variation of flow of water from Rivers Nzoia, Yala and Sio into Lake Victoria. Proceedings of Lake Victoria Environment Management Programme (LVEMP), First regional scientific conference 3rd-7th December 2001, Kisumu, Kenya.

Schelhas, J. (1996). Land use choice and change: intensification and diversification in the lowland tropics of Costa Rica. Human Organization 55, 298-306.

Saura, S. (2003). Effects of remote sensor spatial resolution and data aggregation on selected fragmentation indices. Landscape Ecology 19: 197-209.

Serneels, S., & Lambin, E. F. (2001). Proximate causes of land-use change in Narok district, Kenya: a spatial statistical model. Agriculture, Ecosystem and Environment 85, 65-81.

Stonich, S. C. (1993). The political ecology of poverty and environmental destruction in Honduras. Westview Press Inc, Oxford.

Thenya, T. (2006). Analysis of Macrophyte Biomass Productivity, Utilization and its Impact on Various Eco-Types of Yala Swamp, Lake Victoria Basin, Kenya. Ecology and Development series No. 45, 2006. Cuvillier Verlag Gottingen.

Turner, M. G., O'Neill, R. V., Gardner, R. H., & Milne, B. T., (1989). Effects of changing spatial scale on the analysis of landscape pattern. Landscape Ecology 3, 153-162.

Turyahabwe, N., Kakuru, W., Tweheyo, M., & Tumusiime, D. M. (2013). Contribution of wetland resources to household food security in Uganda Agriculture & Food Security, 2,5.

U.S., Geological Survey. (2001). Landsat ETM scene, WRS-2 Path (170), Row (060), level orthorectified. Sioux Falls, South Dakota: USGS.

U.S., Geological Survey (1973). Landsat MSS scene, WRS- 1, Path (183), Row (060), level orthorectified. Sioux Falls, South Dakota: USGS.

Verhoeven, J. T. A., & Setter, T. L., (2010). Agricultural use of wetlands: opportunities and limitations. Annals of Botany 105, 155–163.

Von Thunen, J. H. (1966). Der isolierte Staat in Beziehung auf Landwirtschaft un Nationalokonomie. In: Serneels S, Lambin EF (2001). Proximate causes of land-use change in Narok district, Kenya: a spatial statistical model. Agriculture, Ecosystem and Environment 85, 65-81.

Woo, M. K., Winter, T. C. (1993). The role of permafrost and seasonal frost in the hydrology of northern wetlands in North America, Journal of Hydrology, 141, 5–31.

Woo, M. K., & Young, K. L. (2006). High Arctic wetlands: their occurrence, hydrological characteristics and sustainability, J. Hydrology320, 432–450.

Wood, C. H., & Skole, D. (1998). Linking satellite census and survey data to study deforestation in the Brazilian Amazon. In: B. Mertens, W. D., Sunderlin, O., Ndoye, Lambin, E. F., 2000. Impact of macroeconomic change on deforestation in South Cameroon: integration of household survey and remotely-sensed data. World Development 28 (6, 983-999.

Wu, J., Jelinski, D. E., Luck, M., & Tueller. P. T. (2002). Multiscale analysis of landscape heterogeneity: scale variance and pattern metrics. Geographical Information Science 6, 6-19.

Yadav, S., Rizvi, I., & Kadam, S. (2015). Comparative Study Of Object Based Image Analysis On High Resolution Satellite Images For Urban Development. International Journal Of Technical Research And Applications. Special Issue 31(September, 2015), 105-110 105

Younos, T., & Parece, T. E. (eds.) (2015). Using Remote Sensing to Map and Monitor Water Resources in Arid and Semiarid Regions. Advances in Watershed Science and Assessment, The Handbook of Environmental Chemistry 33, Springer International Publishing Switzerland, DOI 10.1007/978-3-319-14212-8_2.