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Evaluation of Effects of Wetland Conversion on Quantitative Soil Properties and Water Quality in Namutumba District, Uganda

Charles K.Twesigye*, Jonathan Abaho and Norah M.Mutekanga
Department of Biological Sciences, Faculty of Science,
Kyambogo University, P.O. Box 1, Kyambogo, Kampala, Uganda
* E-mail of the corresponding author: twesigyeck@yahoo.com

Abstract

There are many land use changes happening in Uganda whose impacts have not yet been well investigated. This study determined the land use changes that occurred in Namutumba districts between 1988 and 2018. Landsat images of resolution of 30 m were downloaded from landsat.org for a period of 30 years; 1988, 1998, 2008 and 2018. Image classification was done using Maximum Likelihood Classification and percentage change in areas under different land uses were determined for years; 1988-1998, 1998-2008 and 2008-2018. Representative soil samples and water samples were collected from cultivated wetlands and those that were not cultivated in the different water systems of Naiyede, Mpologoma, Naigomba and Namakoko in Namutumba district. The soil samples were analyzed for pH, organic matter (OM), nitrogen (N), phosphorous (P), potassium (K), boron (B), calcium (Ca), magnesium (Mg), copper (Cu), zinc (Zn), iron (Fe), manganese (Mn), cadmium (Cd) and lead (Pb)in the soil. The water samples were analyzed for colour, total hardness (TH), total dissolved solids (TDS), total suspended solid (TSS), turbidity, nitrates ($NO3^-$), total solids (TS), pH, alkalinity, conductivity (Co), Pb, Mg, Na, Ca, chromium (Cr), Fe, phosphates (PO_4^{3-}), chloride (Cl), Cd and sulphates (SO_4^{2-}). Results of land use change indicated a reduction in areas under open water, wetlands, woodland and bush lands and increase in built up areas and wetlands. Cultivation of wetlands significantly ($p<0.05$) affected quantitative soil properties; pH, OM, N, P, Na, Cu and Cd while K, Ca, Mg, Zn, B, Fe, Mn and Pb were not significantly ($p>0.05$) affected by cultivation. Cultivation of wetlands significantly increased water quality parameters; TDS, TSS, conductivity, Na, Ca, Cl, SO_4^{2-}, PO_4^{3-} and TH. On the other hand, water quality parameters; pH, Co, alkalinity, Mg, Cr, Fe, Cd and $NO3^-$ were not affected by cultivation. It can be concluded that most of the fragile ecosystems in Namutumba District is being converted into built up areas and farmlands and it is negatively affecting some of the soil and water quality parameters. These results are crucial in informing policy makers in designing by-laws and policies for protecting fragile ecosystems such as wetlands from degradation.

Keywords: Namutumba District, Soil properties, Ugand**a,** Water quality, Wetland conversion,

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1. Introduction

Wetlands are important in regulating climate, filtering of contaminants, sink for carbon storage and a source of food that supports the livelihood of many people in the Sub-Sharan Africa (Wagner *et al*., 2020). Despite these roles, wetlands in Uganda and the world at large continue to experience great changes while being transformed to other land uses. Available research shows that wetlands are mainly located in places that occupied by humans, especially agricultural and urban regions (Ehrenfled, 1991, Neely, 1989). Research has also shown negative effects on wetland species and ecosystem function can be expected in such areas due to human activities (Ehrenfled, 1991; Moore, 1989; Morgan, 1986 and Morris, 1991). Approximately 160000 Sq.km of wetland globally has been drained for subsistence farming (Williams, 1991). Subsistence farming forms two types; primitive and intensive. The former involves slashing and burning vegetation and pastoral farming on marginal areas while the latter is practiced in fertile land due to lack of enough land thus forcing farmers to maximize food production on relatively small fields (Weceke and Kimenju, 2007). Uganda is faced with intensive subsistence farming in most areas due to the high population density and widespread poverty levels. This puts the country at a risk of land degradation and deforestation with its associated effects of climate change especially among densely populated rural districts like Kabale and Namutumba (Dietrich, 2009).

Over the past years, great changes have occurred concerning the state of wetlands in Uganda. Wetlands play important roles among them of which include waste recycling, flood prevention, serve as breeding sites for fish species, habitat for wildlife, maintain grounds for water supply and improve water quality. Wetland soils may be drained to grow crops at such subsistence levels but production will be short term. These activities which at first seemed to be sustainable will no longer be supported by such wetland soils. Sustainability of agriculture in wetlands that are located in regions of increasing food insecurity and fast growing population is very important in ensuring their survival.

However, there is scanty information on effect of wetland conversion on soil properties on water quality in Uganda. The few studies have focused on change of forest ecosystems into other land uses and effects on major soil properties (Mwanjalolo *et al*., 2018; Abonyo *et al*., 2007; NEMA, 2005 and Wasige *et al*., 2013). Therefore, this study determined the trend in wetland conversion and determined the effect of these conversions on a broad range of quantitative soil properties and water quality parameters including heavy metals in Namutumba District in Uganda.

Recently, wetlands in Namutumba District have come under the attention of the environmental protection bodies in Uganda because of the high rate wetland conversion. However, the extent of this wetland conversion and associated effects on the environment is not well known. This study tracked changes in land uses that occurred in Namutumba Districts between 1988 and 2018. Findings of this research will contribute towards informing any changes to the existing land uses with purposes of promoting soil and water quality. In many developing countries, local communities depend primarily on wetland. These communities utilize them for their livelihoods through reed harvesting, fishing, clay mining and agriculture (Adelaida, 2000).

1.1 Impact of agricultural activities on wetlands

Sustainable utilization of wetlands is very important for their survival while also helping the people that benefit from them to survive. Sustainability has to do with economic, ecology and social aspects (Falvey, 2004). According to Brunt land commission sustainability is defined as using the available resources to meet the present needs without halting those of the future generations (World Commission of Environmental Development, 1987). From this definition, we can say wetland degradation is the process by which wetlands are used until they can longer maintain their uses of supporting and regulating the ecosystem services that are beneficial to both the present and future generations. Continuous and unsustainable cultivation does not only cause loss of the wetlands it also leads to loss of soil fertility. The processes leading to the formation of wetland soils involves special chemical conditions that are favored by waterlogged environments. There is an increasing focus and mindset change on wetlands (Wilson, 1996). The conservation and management of wetlands that are not defined with reference to Ramsar convention remains in the hands of national and local governments where they are located. Strategic management policies implemented at both national and local levels can play important roles in ensuring sustainability and survival of these wetland ecosystems. Implementation of such strategies requires up-to-date data that is collected regularly and over an extensive period of time in places where these wetlands face great threats from human population.

1.2 Wetland assessment and effective management

Hedman (2019) revealed significant differences in organic carbon (OC) and bulk density (BD) among land use types; farmland, natural grasses, woodland and wetlands in Uganda. Wetland soils had higher amounts of OC, pH and lower BD compared to farmland, natural grasses and woodland. Agricultural land had higher P contents compared to wetlands and restored wetlands. Wetlands had higher N compared to other ecosystems. Ca was higher in agricultural land and restored wetland compared to non-disturbed wetlands. Their results further indicated higher OC in wetlands compared to other ecosystems.

It can be concluded that most of the above investigations were conducted in China with few studies in East Africa((Hedman, 2019; Ewing *et al*., 2012; Wang *et al*., 2014, Zhao *et al*., 2020; Sun *et al*., 2011; Wang *et al*., 2012, Lian *et al*., 2013; Osinuga and Oyegoke, 2019; Arunrat, 2020 and Mujiyo *et al*., 2018). Similarly, none of the above studies determined the effect of cultivation of wetlands on heavy metals and most of the studies concentrated on OM, soil pH and macro nutrients. This study incorporated the effect of seasons, cultivation of wetlands on many quantities of soil properties including micro nutrients and heavy metal concentrations in selected wetlands in one of the districts; Namutumba in Uganda.

1.3 Effect of cultivation of wetlands on water quality

Previous studies show that mean concentration of phosphates and total P and nitrate were higher in agricultural land and much lower in restored wetland. Total nitrogen was highest in wetland ecosystems compared to cultivated land (Bruland *et al*. (2003). They further noted that these results were connected with periods of farming activity. With the exception of Tumwesigye (2012), it can be concluded that most of the above studies were conducted in other countries other than Uganda (Bruland *et al*., 2003; Moreno-Mateos *et al*., 2009; Uwimana, 2018;2019). None of the above studies incorporated the effect of seasons on water quality.

2. Materials and Methods

2.1 Study area

The study area is located in South-eastern part of Uganda, approximately 140 km from Kampala city. Namutumba District is bordered by Iganga District in the South, Bugiri in the South-East, Kaliro, Kibuku in the North and Butalejja in the East. The meteorological data from Namutumba district is typical of Eastern region of Uganda. There is tropical climate characterized by comparatively small variations in temperatures. The District hasbiannual season with first rains covering March to June and second rain August to November.

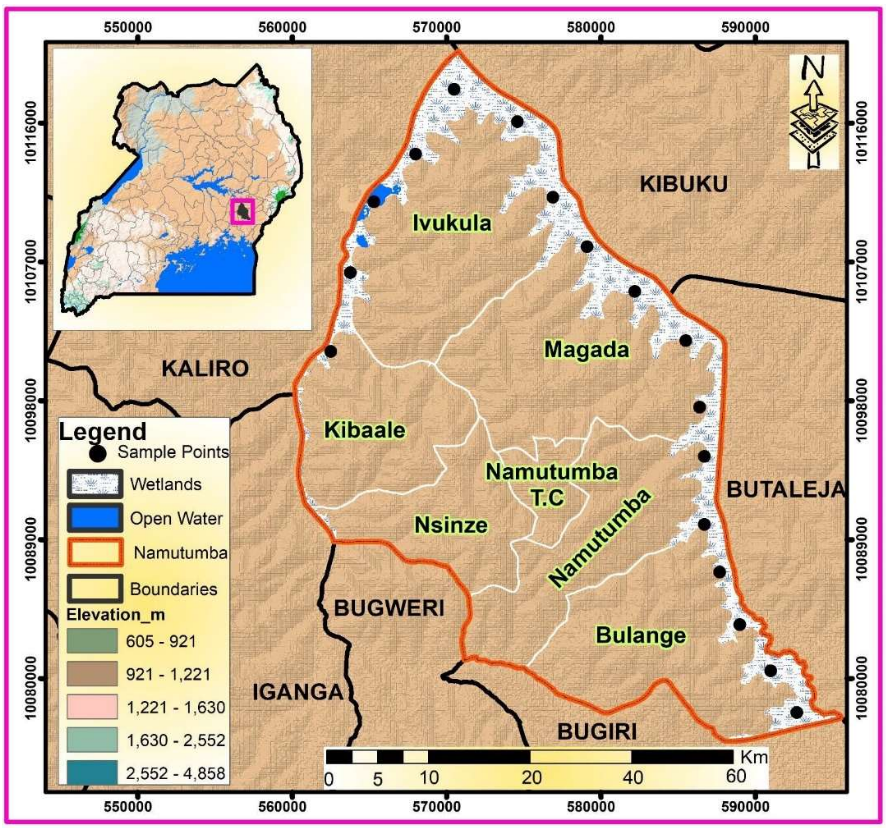

Figure 1 Study sites in Namutumba District

Agriculture in the study are is based on crop and animal husbandry. Animals kept include; cattle, goats, sheep, pigs, rabbits, chicken, turkeys, ducks. There is also tourism potential in the District with some different species of birds living along the Mpologoma river which are good for bird viewing. Other attractions include wetlands stretching from East to North-West of the District and there are rare situnga and reedbuck, vervet monkeys around these wetlands.

2.2 Land use change detection

2.2.1 Acquisition of data

Landsat TM and ETM images were downloaded from landsat.org for a period of 20 years (Table 3.1). The images with cloud cover between 10-20% were downloaded for years: 1988, 1998, 2008 and 2018 during the months of

February, June, August and September. February and June falls in the first rainy season and August and September falls in the second rainy seasons of Uganda. These images were used to identify the existing land uses at that time. Hard copy maps e.g. vegetation maps and land use maps were obtained from the GIS unit at National Agricultural Research Laboratories was utilized to validate the results of the land use change analysis.

Table 2.1: Datasets used for analysis of land use change in Namutumba District. TM = thematic maps, m = meters and USGS = United States geological survey. Feb = February, Aug = August and Sep = September.

Dataset	Date of Acquisition	Path	Row	Resolution	Source
Landsat 4-5 TM C1 Level 1	18 Feb 1988	170	059	30 m x 30 m	USGS
	18 Feb 1988	171	059		
Landsat 4-5 TM C1 Level 1	22 June 1998	170	059	30 m x 30 m	USGS
	07 Aug 1998	171	059		
Landsat 4-5 TM C1 Level 1	19 Sep 2008	170	059	30 m x 30 m	USGS
	28 Sep 2008	171	059		
Landsat 8 OLI/TIRS C1 Level 1	24 Sep 2018	170	059	30 m x 30 m	USGS
	03 Feb 2018	171	059		

2.2.2 Image classification

Land use map of 1998 was used to verify the Landsat classification map. ArcGIS10.1 was used for the post classification change evaluation of the land cover maps to identify the land use changes that occurred between 1988 and 2018. The outcomes of these analyses were presented in terms of maps and the percentage changes in land use were presented in a tabular form.

*2.2.*3 Trend in land use change

The area (in km^2) covered by different land uses for each of the years; 1988, 1998, 2008 and 2018 were obtained from the GIS software and displayed in a tabular form. Using the total area of Namutumba District, these areas were converted into percentages. The main crops grown in wetlands (cultivated) were rice, maize and vegetables. Roots, gravels and stones were removed from these samples. They were bulked, labeled and transported to a soil laboratory for analysis at Makerere University for chemical analysis.

Cadmium (Cd) and lead (Pb). N were measured using Kjedahl (Elliott *et al*., 1999). K was measured using flame photometer. Available P was determined using calorimetric method.The concentration of Pb and Cd was measured using flame atomic absorption spectrometer.

Ten (10) representative water samples were collected differently from cultivated and uncultivated areas in each of the study sites. At the laboratory, the water samples were analyzed according to Standard methods for examination of water and wastewater following procedures described in APHA (1998).

The chemical properties of water analyzed were nitrates, pH, alkalinity, conductivity, lead, magnesium, sodium, calcium, chromium, iron, phosphates, chloride, cadmium and sulphates. pH was measured directly using a pH meter and conductivity using a conductivity meter. Turbidity levels were measured in Nephelometric units (NTUs) using the HACH 2100A turbidity meter. Colour (apparent colour) was determined using a spectrophotometer (DR

20800 model). Total nitrogen concentration was read directly using DR4000 spectrophotometer at 543 nm. Phosphorus and chlorides were determined calorimetrically method using visible spectrophotometer (model DR 3800-HACH). Sodium was determined using a flame photometer (Model CORNING M410).

2.2.4 Statistical data analysis

The mean of parameters (±SE) and one-way analysis of variance (ANOVA) followed by a post hoc multiple comparison (Tukey's test). ANOVA was used because the data was normally distributed and met the condition of equality of variances.

3. Results

3.1 Land uses identified

Table 3.1 presents the land uses identified in Namutumba District. From the image analysis and ground- truthing, the land uses identified in Namutumba District included woodland, farmland, bush land, built-up areas, wetlands and open water.

Table 3.1**:** Land uses identified in Namutumba District. (**Source:** student).

Land use type	**Description**
Woodland	Evergreen trees that naturally or artificially grown in reserved land along flatlands, riverbanks and hills.
Farmland	Food crops such as green vegetables, cereals, legumes and tubers for home consumption
Bush land	Evidenced with shrubs, thickets, figs and grasslands
Built-up areas	Evidenced with buildings, roads and communication structures.
Wetlands	Evidenced by both temporal and permanent swamps.
Open water	Evidenced by lakes, ponds, rivers and springs.

3.2 Areas covered by different land uses in Namutumba District in 1988, 1998, 2008 and 2018

The land uses changes that occurred in Namutumba District between 1988 and 2018 are presented in Table 3.2 and Figures; 3.1, 3.2, 3.3 and 3.4. In 1988, woodland occupied the largest area 37%, followed by wetland (12%), bush land (19%) and farmland (16%). 12% and 4% of the areas were under built-up areas and open water respectively. In 1998, the land covers with the largest areas were wetland, farmland, and bush land at 22%, 12%, and 15% respectively. The percentage of areas covered by woodland, built-up areas and open water were 35%, 12% and 3% respectively. Farmlands and bush land occupied the greatest areas in 2008 with percentage coverage of 34% and 22% respectively. The smallest area was under open water (1.4%). In 2018, farmlands and built-up areas had the biggest coverage of 36% and 26% respectively. Still open water had the small coverage (0.6%).

Table 3.2: Percentage in land use cover in Namutumba District between 1988 and 2018

LU/LC	1988		1998		2008		2018	
	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%
Built-up	95.8	11.76	95.9	11.78	86.4	10.63	212.5	26.12
Bush land	154.5	18.99	121.4	14.92	180.2	22.16	84.8	10.42
Woodland	131.2	16.12	101.0	12.41	102.7	12.63	83.8	10.30
Open water	31.2	3.84	25.5	3.14	11.4	1.40	4.8	0.59
Farmland	98.6	12.11	182.8	22.46	280.3	34.44	288.9	35.50
Wetlands	302.3	37.16	287.1	35.29	152.5	18.74	138.8	17.06
TOTAL	**813.6**		**813.6**		**813.6**		**813.6**	

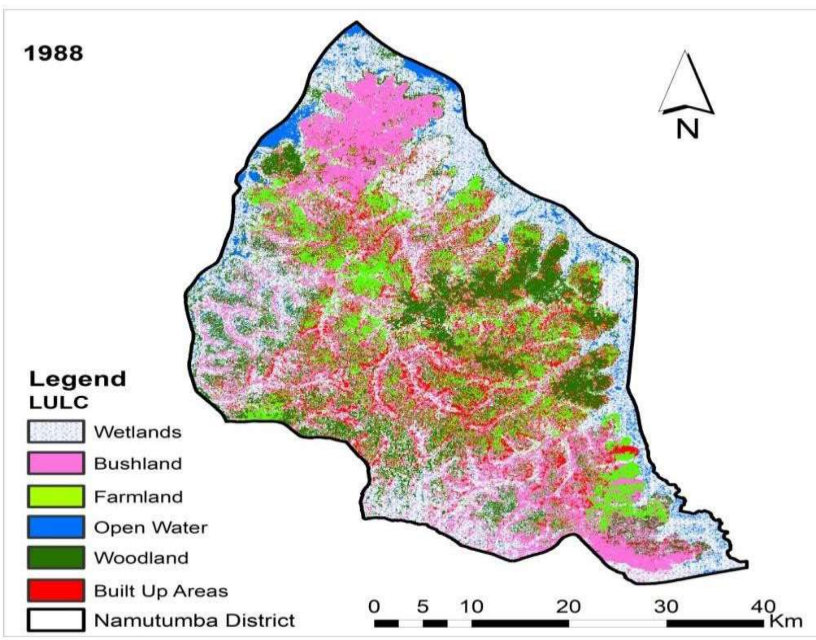

Figure 3.1: Land use in Namutumba District in 1988

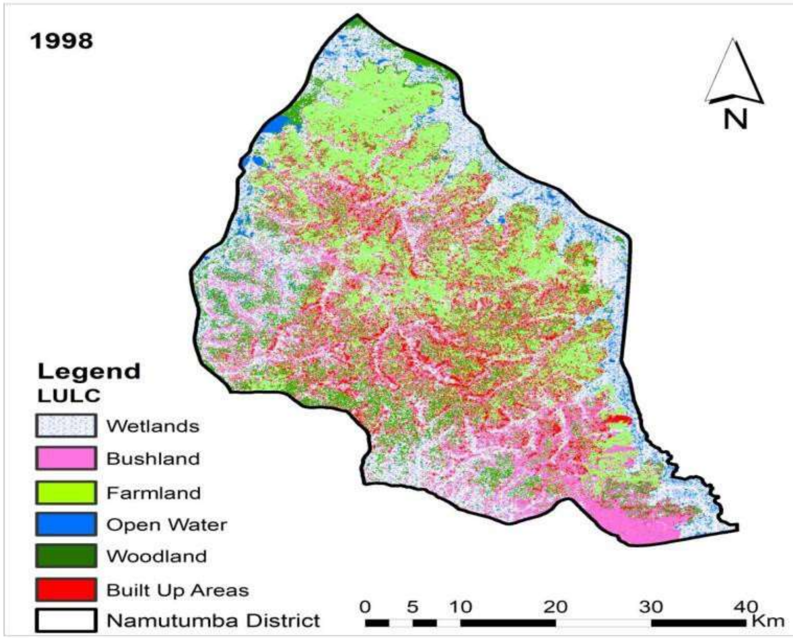

Figure 3.2: Land use in Namutumba District in 1998

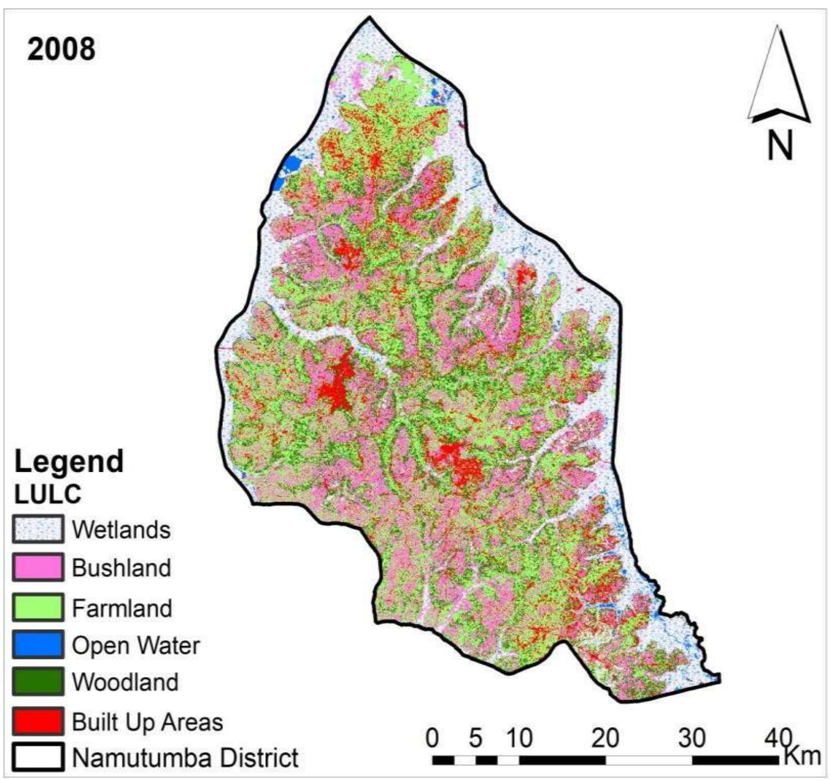

Figure 3.3: Land use in Namutumba District in 2008

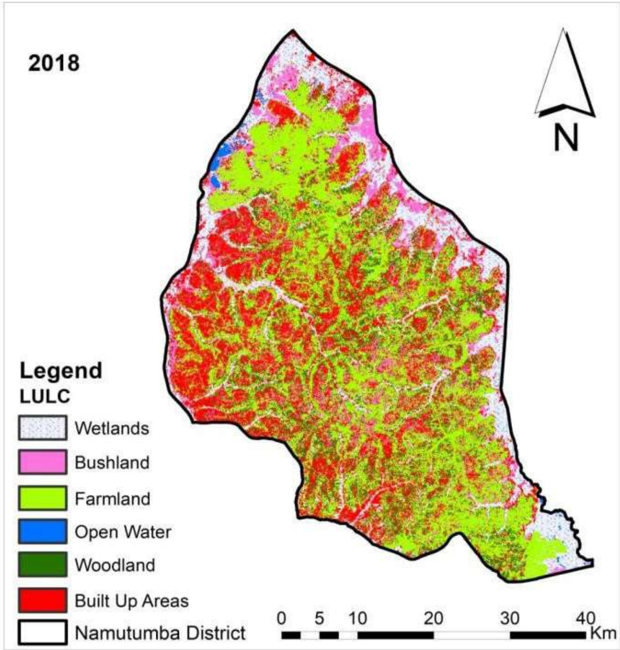

Figure 3.4: Land use in Namutumba District in 201

Accuracy assessment was carried out for classified map of 2018 to examine the agreement between produced land use map of 2018 and what existed on the ground. The classified map of 2018 achieved overall accuracy value of 80% indicating that the land use map met the criteria for accurate classification. An accuracy of 60% and above is recommended for any classified maps (Congalton, 1991). Generally, there was a reduction in areas under open water throughout the years; 1988, 1998, 2008 and 20018. The highest reduction (1.74%) happened between 1998 and 2008. Built-up areas increased by 0.02% between 1988 and 1998. It further increased sharply by 15% between 2008 and 2018. Farmlands increased by 10% and 12% between 1988-1998 and 1998-2008 respectively. Conversion of wetlands to other land uses was rampant between 1998 and 2008. Areas covered by wetlands reduced by 17% between 1998 and 2008. Areas covered by bush land also reduced by 12% between 2008 and 2018.

Tables; 3.4 and 3.5 present the average of quantitative soil properties as affected by cultivation, and location respectively. Generally, cultivated wetlands had higher values of pH, OM, N, P, Na, Cu and Cd. Cultivation of wetlands increased amounts in Na and Cd in the soils with average values of 50.86 ppm, 0.17 $cmol_{(+)}$/kg soil and 0.06 ppm respectively in cultivated wetlands as compared to 18.58 ppm, 0.11 $cmol_{(+)}$/kg soil and 0.04 ppm respectively in uncultivated wetlands. On the other hand, there were significantly ($p<0.05$) lower average values of quantitative soil properties; pH, OM, N and Cu in cultivated wetlands (5.1, 2.25 %, 0.12 % and 1.19 ppm respectively) as compared to the uncultivated (5.6, 3.61 %, 0.19% and 1.54 ppm respectively). Quantitative soil properties; K, Ca, Mg, Zn, B, Fe, Mn and Pb were not significantly ($p>0.05$) affected by cultivation of wetlands.

There were higher average values of P and Ca (54.55 ppm and 8.37 $cmol_{(+)}$/kg soil respectively) in Mpologoma river system compared to other river systems. Similarly, Zn, K and B were significantly ($p<0.05$) higher in Namakoko river system with average values of 25.6 ppm, 0.85 $cmol_{(+)}$/kg soil and 3.73 ppm respectively as compared to other river systems. The average values of pH, OM, N, Na, Mg, Cu, Fe, Mn and Pb were not significantly ($p>0.05$) different across all the locations.

Table 3.3: Percentage change in land use between 1988 and 2018. % = percentage change in land use. - = reduction in area coverage and + = increase in area coverage. * = significant.

Land uses	**1988-1998 (%)**	**1998-2008 (%)**	**2008-2018 (%)**
Built-up areas	0.02	-1.15	15.49*
Bush land	-4.07	7.24*	-11.74*
Woodland	-3.71	0.22	-2.33
Open water	-0.7	-1.74	-0.81
Farmland	10.35*	11.98*	1.06
Wetlands	-1.87	-16.55*	-1.68

Tables; 3.4 and 3.5 present average quantitative soil properties as affected by cultivation, and location respectively. Generally, cultivation of wetlands had a significant ($p<0.05$) effect on quantitative soil properties; pH, OM, N, P, Na, Cu and Cd. Cultivation of wetlands significantly ($p<0.05$) increased the amounts of P, Na and Cd in the soils with average values of 50.86 ppm, 0.17 $cmol_{(+)}$/kg soil and 0.06 ppm respectively in cultivated wetlands as compared to 18.58 ppm, 0.11 $cmol_{(+)}$/kg soil and 0.04 ppm respectively in uncultivated wetlands. On the other hand, there were significantly ($p<0.05$) lower average values of quantitative soil properties; pH, OM, N and Cu in cultivated wetlands (5.1, 2.25 %, 0.12 % and 1.19 ppm respectively) as compared to the uncultivated (5.6, 3.61 %, 0.19% and 1.54 ppm respectively). Quantitative soil properties; K, Ca, Mg, Zn, B, Fe, Mn and Pb were not significantly ($p>0.05$) affected by cultivation of wetlands.

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Table 3.4: Effect of cultivation on quantitative soil properties. Trt = treatment, Uncul = uncultivated wetland, Cul = cultivated wetland. Soil pH = acidity or alkalinity of soil, OM = organic matter (%), N = nitrogen (%), P = available phosphorus (ppm), K = potassium (cmol(+)/kg soil), Na = sodium (cmol(+)/kg soil), Ca = calcium (cmol(+)/kg soil), Mg = magnesium (cmol(+)/kg soil), Cu = copper (ppm), Zn = zinc (ppm), Fe = iron (ppm), Mn = manganese (ppm), Pb = lead (ppm) and Cd = cadmium (ppm). % = percentage, ppm = parts per million, $cmol_{(+)}$/kg soil = centimole of positive charge per kilogram of soil. a and b = letters for separation of means. Means within a column followed by the same letter (a or b) are not significantly different at 5% level. a and b = letters used for separation of means. (**Source:** student).

Trt	**pH**	**OM**	**N**	**P**	**K**	**Na**	**Ca**	**Mg**	**Cu**	**Zn**	**B**	**Fe**	**Mn**	**Pb**	**Cd**
Uncul	5.6^a	3.61^a	0.19^a	18.58^b	0.71^a	0.11^b	7.21^a	1.99^a	1.54^a	18.75^a	3.18^a	98.41^a	32.49^a	0.02^a	0.04^b
Cul	5.1^b	2.25^b	0.12^b	50.86^a	0.73^a	0.17^a	7.30^a	2.36^a	1.19^b	20.70^a	2.80^a	98.37^a	26.36^a	0.02^a	0.06^a
p-value	*0.00*	*0.00*	*0.00*	*0.00*	*0.74*	*0.00*	*0.89*	*0.10*	*0.03*	*0.50*	*0.63*	*0.99*	*0.06*	*0.81*	*0.01*

Table 3.5: Effect of river systems on quantitative soil properties. Mp = Mpologoma, Ng = Naigomba, Ny = Naiyede and Na = Namakoko. Soil pH = acidity or alkalinity of soil, OM = organic matter (%), N = nitrogen (%), P = available phosphorous (ppm), K = potassium (cmol(+)/kg soil), Na = sodium (cmol(+)/kg soil), Ca = calcium (cmol(+)/kg soil), Mg = magnesium (cmol(+)/kg soil), Cu = copper (ppm), Zn = zinc (ppm), Fe = iron (ppm), Mn = manganese (ppm), Pb = lead (ppm) and Cd = cadmium (ppm). % = percentage, ppm = parts per million, $cmol_{(+)}/kg$ soil = centimole of positive charge per kilogram of soil. Means within a column followed by the same letter (a or b) are not significantly different at 5% level. a and b = letters used for separation of means. (**Source:** student).

River Systems	pH	OM	N	P	K	Na	Ca	Mg	Cu	Zn	B	Fe	Mn	Pb	Cd
Mp	5.3^{a}	2.40^{a}	0.15^{a}	54.55^{a}	0.76^{ab}	0.18^{a}	8.37^{a}	2.29^{a}	1.52^{a}	20.23^{ab}	3.42^{a}	105.68^{a}	27.08^{a}	0.04^{a}	0.04^{b}
Ng	5.2^{a}	3.00^{a}	0.15^{a}	24.57^{b}	0.65^{b}	0.12^{a}	7.00^{ab}	2.02^{a}	1.21^{a}	13.48^{b}	1.70^{b}	94.73^{a}	28.85^{a}	0.01^{a}	0.04^{ab}
Ny	5.2^{a}	3.05^{a}	0.16^{a}	27.90^{b}	0.62^{b}	0.13^{a}	5.80^{b}	1.98^{a}	1.33^{a}	19.58^{ab}	3.12^{a}	91.63^{a}	31.21^{a}	0.02^{a}	0.04^{b}
Na	5.6^{a}	3.29^{a}	0.16^{a}	31.85^{ab}	0.85^{a}	0.13^{a}	7.90^{a}	2.41^{a}	1.42^{a}	25.60^{a}	3.73^{a}	101.52^{a}	30.57^{a}	0.03^{a}	0.07^{a}
p-value	*0.155*	*0.33*	*0.98*	*0.05*	*0.083*	*0.31*	*0.01*	*0.47*	*0.60*	*0.02*	*0.01*	*0.46*	*0.82*	*0.23*	*0.07*

The effect of cultivation of wetlands and river systems on water quality is presented in Tables 3.6 and 3.7. Cultivation of wetland soils significantly ($p<0.05$) affected water quality parameters; TDS, TSS, conductivity, Na, Ca, TH, Cl, SO_4^{2-} and PO_4^{3-}. On average, significantly ($p<0.05$) higher values of TDS, TSS, conductivity, Na, Ca, TH, Cl, SO_4^{2-} and PO_4^{3-} (3.16 mg/L, 0.62 mg/L, 127 µS/cm, 19.29 mg/L, 5.2 mg/L, 2.37 mg/L, 23.8 mg/L, 32.26 mg/Land 74.00 mg/L respectively) were recorded in water samples obtained from cultivated wetlands as compared to the uncultivated ones with an average values of 2.29 mg/L, 0.36 mg/L, 93.48 µS/cm, 12.48 mg/L, 1.91 mg/L, 1.58 mg/L, 13.72 mg/L, 19.54 mg/L and 15.13 mg/L respectively. Conversely, cultivation of wetlands did not significantly ($p>0.05$) affect water quality parameters; pH, Co, Tur, Alk, Pb, Mg, Cr, Fe, NO_3^- and Cd. Naiyede river system had significantly ($p<0.05$) higher values of pH and Alk (6.9 and 1.9 mg/L respectively) compared to other river systems. TDS, Cr and Tur were signifcanlty higher in Naigomba river system compared to other systems with average values of 3.38 mg/L, 0.19 mg/L and 0.77 mg/L respectively. Namakoko had significantly higher average values of Co and TSS (2.24 TUC and 0.65 mg/L respectively) compared to other river systems.

Table 3.6: Effect of cultivation of wetlands on water quality. Trt = treatment, Cul = cultivated wetlands, uncul = uncultivated wetlands. Co = color (TCU), concentration of H^+, Tur = turbidity (NTC), TDS = total dissolved solids (mg/L), TSS = total suspended solids (mg/L), Cond = conductivity (µS/cm), Alk = alkalinity (mg/L), Pb = lead (mg/L), Mg = magnesium (mg/L), Na = sodium (mg/L), Ca = calcium (mg/L), Cr = total chromium (mg/L), Fe = iron (mg/L), NO^- = nitrates (mg/L), Cl = chlorides (mg/L), Cd = cadmium (mg/L), SO_4^{2-} = sulphates (mg/L), PO_4^{3-} = phosphates (mg/L) and TH = total hardness (mg/L). Means in the same column followed by the same letter (a or b) are not significantly different at 5%. a and b = letters used for separation of means. (**Source:** student).

Trt	Ph	Co	Tur	TDS	TSS	Cond	Alk	Pb	Mg	Na	Ca	Cr	Fe	NO_3^-	Cl	Cd	SO_4^{2-}	PO_4^{3-}	TH
Cul	6.7^{a}	1.49^{a}	0.40^{a}	3.16^{a}	0.62^{a}	127.00^{a}	1.50^{a}	0.02^{a}	1.30^{a}	19.29^{a}	5.20^{a}	0.15^{a}	0.20^{a}	4.78^{a}	23.8^{a}	0.01^{a}	32.26^{a}	74.00^{a}	2.37^{a}
Uncul	6.5^{a}	1.34^{a}	0.46^{a}	2.29^{b}	0.36^{b}	93.48^{b}	0.97^{a}	0.01^{a}	1.04^{a}	12.48^{b}	1.91^{b}	0.12^{a}	0.14^{a}	2.60^{a}	13.72^{b}	0.02^{a}	19.54^{b}	15.13^{b}	1.58^{b}
p-value	*0.38*	*0.62*	*0.79*	*0.04*	*0.03*	*0.02*	*0.117*	*0.36*	*0.12*	*0.01*	*0.03*	*0.20*	*0.15*	*0.07*	*0.01*	*0.44*	*0.03*	*0.00*	*0.01*

Table 3.7 Effect of river systems on water quality. Loc = location, Ny = Naiyede, Na = Namakoko, MP = Mpologoma and Ng =Naigomba, Co = color (TCU), concentration of H^+, Tur = turbidity (NTC), TDS = total dissolved solids (mg/L), TSS = total suspended solids (mg/L), Cond = conductivity (μS/cm), Alk = alkalinity (mg/L), Pb = lead (mg/L), Mg = magnesium (mg/L), Na = sodium (mg/L), Ca = calcium (mg/L), Cr = total chromium (mg/L), Fe = iron (mg/L), $NO3^-$ = nitrates (mg/L), Cl = chlorides (mg/L), Cd = cadmium (mg/L), $SO4^{2-}$ = sulphates (mg/L), $PO4^{3-}$ = phosphates (mg/L) and TH = total hardness (mg/L). Means in the same column followed by the same letter (a or b) are not significantly different at 5%. A and b are letters used for separation of means. (**Source**: student).

Location	pH	Co	Tur	TDS	TSS	Cond	Alk	Pb	Mg	Na	Ca	Cr	Fe	$NO3^-$	Cl	Cd	$SO4^2$	$PO4^{3-}$	TH
Ny	6.9^a	0.91^b	0.14^a	2.16^b	0.42^{ab}	106.20^a	1.97^a	0.013^{ab}	1.07^a	15.18^a	4.66^a	0.13^b	0.22^a	4.21^a	19.83^a	0.01^a	33.5^a	40.75^a	1.70^a
Na	6.8^a	2.24^a	0.74^a	3.09^{ab}	0.65^a	130.00^a	1.19^{ab}	0.005^b	1.09^a	16.93^a	3.33^a	0.12^b	0.13^a	3.30^a	23.53^a	0.03^a	18.28^a	43.75^a	2.34^a
Mp	6.7^{ab}	1.15^b	0.07^b	2.27^{ab}	0.26^b	116.75^a	0.66^b	0.035^a	1.09^a	16.48^a	4.30^a	0.09^b	0.19^a	1.87^a	12.20^a	0.01^a	20.33^a	49.25^a	1.87^a
Ng	6.2^{ab}	1.36^b	0.77^a	3.38^a	0.62^a	88.00^a	1.14^b	0.010^b	1.43^a	14.95^a	1.95^a	0.19^a	0.13^a	5.38^a	19.48^a	0.01^a	31.50^a	44.50^a	2.00^a
p-value	*0.04*	*0.00*	*0.01*	*0.09*	*0.08*	*0.28*	*0.0281*	*0.08*	*0.342*	*0.96*	*0.65*	*0.01*	*0.072*	*0.14*	*0.33*	*0.93*	*0.18*	*0.99*	*0.57*

4. Discussion

4.1Land use change that occurred in Namutumba District between 1988 and 2018

Table 4.3 shows a reduction in areas under bush land and wetlands. The population growth with consequent increase in the food demand could have forced people to open more virgin lands therefore conversion of bush land and wood lands into farmlands. Many people could have engaged in agriculture for business to market in the nearby towns and cities. These results are in agreement with results obtained by Malaki (2018) in Nguruman sub-catchment in Kenya. However, it contrasts with results obtained by Cheruto *et al*. (2016) in Mkueni County in Kenya where they got a significant conversion of areas under forests to bushlands.

The results from the study (Table 4.3) further indicated an increase in areas covered by farmlands. The increase in farmlands can still be explained by an increase in population. Still, population growth with consequent increase in food demand could have forced people to convert other land uses into farmlands. These results are in line with results obtained by Alawamy *et al. (2020), Swart* (2016), Mwanjalolo *et al.* (2018), Mogosi (2015) and Malaki (2018).

The increase in human settlements can be explained by population growth which required the construction of more houses to accommodate the growing number of families. This process could have been accompanied by construction of paved and unpaved roads, schools and hospitals in the area. Studies in other parts of the world also obtained similar results. Alawamy *et al*. (2020) in the region of Al- Jabal Al-Akhdar in Libya, Siddhartho (2009) in Kiskatinaw river watershed and Cheruto *et al*. (2016) in their study in Makueni county obtained similar results. Areas under open water also declined (table 4.3). This is attributed to an increase in the number of people leading to increase in the demand of safe water for drinking and water for other uses. This led to drilling of underground water in many areas and there for reduction in areas under open water. The results are in conformity with results obtained by Malaki (2018) in Nguruman catchment in Kenya.

4.2 Effect of cultivation of wetlands on quantitative soil properties

Cultivation of wetlands affected quantitative soil properties; pH, OM, N, P, Na, Cu, Mn and Cd. Cultivation of wetland soils decreased soil pH, OM, N, Cu and Mn. However, amounts of P, Na and Cd were increased in the soils of wetlands as a result of cultivation. Cultivation of wetlands did not affect Ca and Mg. The decrease in OM could be attributed to OM mineralization. Cultivation exposes OM to aerobic conditions and therefore leading to a decline in soil organic carbon (SOC) gradually and ultimately a decrease in OM. This is in agreement with Mujiyo *et al.*

(2018), Arunrat (2020), Hedman (2019), Lian *et al*. (2013), Wang *etal*. (2012) and Wang *et al*. (2014) who obtained lower OM contents in soils of cultivated wetlands. Similarly, the decrease in N, Cu and Mn could be associated with decomposition of OM. Decomposition of OM leads to release of nutrients e.g. N, Cu, Mn and others in the soil. The nutrients released migrate between different ecosystems and therefore a reduction of these nutrients in the soil. In contrast, Ewing *et al*. (2012) obtained greater values of Cu in soils of cultivated wetlands in their study in Carolina Bay because farmers were using farmers were using inputs containing a lot of Cu.

A decrease in soil pH could be connected to loss of OM due to rapid mineralization processes, removal of soil nutrients and application of inorganic fertilizers such as nitrogenous fertilizers. These results are in agreement with studies conducted by Mujiyo *et al.* (2018), Hedman (2019), Lian *et al*. (2013), Wang *et al*. (2012) and Wang *et al*. (2014) who obtained lower OM in soils of cultivated wetlands.

The increase in P could be associated with application of organic and inorganic fertilizers. The management options for crops in these cultivated wetlands could be associated with application of pesticides and other chemicals for management of pests and diseases and sometimes spraying with herbicides to control weeds. The application of these chemicals leads to increase in some toxic elements such as cadmium, arsenic, and selenium in the soil. The increase in Na and Cd in cultivated soils could be attributed to application of chemicals for pests and disease management and weed control. These results are in conformance with results obtained by Ewing *et al*. (2012) in Carolina Bay, and North Carolina. However, it contrasts results obtained by Bruland *et al*. (2003) in Carolina Bay who revealed a reduction in amounts of P in cultivated wetlands.

The no difference in Ca and Mg in cultivated and uncultivated soils could be associated with the presence of the same parent materials in the study areas and of the same weathering rate. Much as cultivated wetlands could have had lower amounts of Ca and Mg, probably the exposure of the parent materials to weathering factors was not enough to cause a difference in the amounts of Ca and Mg. Moreover, weathering takes a long term and probably, the wetlands could have been cultivated for a short term and therefore minimal exposure to weathering factors. The results are in correspondence with results obtained by Bruland *et al*. (2020). They revealed higher amounts of Ca in soils of cultivated wetlands compared to soils of uncultivated wetlands. However, it contrasts results obtained by Osinguga and Oyegoke (2019) who obtained an increase in Ca and Mg in cultivated wetlands.

P, K, Ca, Zn and Cd differed among river systems; Mpologoma, Naigomba, Naiyede and Namakoko. Higher values of P and Ca were recorded in soils of Mpologoma. Similarly, significantly higher values of K, Zn and Cd were observed in soils of Namakoko. The higher amounts of P and Ca in the Mpologoma area might be associated with the presence of rocks that contain minerals P and Ca in the area. P and Ca are mainly obtained from the weathering of rocks which act as parent materials for these elements.

Namakoko area has higher amounts of K and Zn and these could be associated with decomposition of organic matter. The higher amounts of Cd could be associated with the use of chemicals for managing pests and diseases and weeds. This data is in conformity with studies conducted by Wang *et al*. (2012) and Wang *et al*. (2014).

4.3 Effect of cultivation of wetlands on quality of water

Cultivation of wetlands affected the properties of water quality such as TDS, TSS, TH, conductivity, Na, Ca, Cl, $SO4^{2-}$, and PO $^{3-}$. TDS, TSS, TH, conductivity, Na, Ca, Cl, $SO4^{2-}$, and $PO4^{3-}$ were higher in water samples collected from cultivated wetlands compared to the uncultivated ones.

The higher amounts of TDS, TSS and TH could be associated with a lot of soil disturbance. Cultivation of soil breaks soil particles; sand, silt and clay and this leads to some solids remaining suspended in the water. The breaking of soil particles also exposes some minerals especially bonded to clay to break and dissolve in the water. The increase in other minerals such as Ca, Cl, $SO4^{2-}$, and $PO4^{3-}$ could be associated with weathering of rock minerals. The quality of water significantly varied in the wetlands situated in different locations. Colour, pH, turbidity, TDS, TSS, alkalinity, Pb and Cr were significantly different among locations. The increase in colour, turbidity, TDS and TSS in Namakoko and Naigomba could be associated with a lot of soil disturbance and probably, the areas around Namakoko and Naigomba could be having bare land with agricultural activities taking place on land close to the wetlands. Namakoko area could also be associated dominantly with clayey soils which makes it dissolved in water causing the obtained colour and increasing the amounts of TSS in the water. The increase in Cr and Pb in Naigomba and Mpologoma respectively could be associated with the use of chemicals for managing weeds, pests and diseases.

5. Conclusions and Recommendations

There was a reduction in areas under open water, wetlands, woodland and bush lands and an increase in built up areas and wetlands between 1988 and 2018. Cultivation of wetlands significantly affected quantitative soil properties pH, OM, N, P, Na, Cu, Mn and Cd while K, Ca, Mg, Zn, Fe and Pb were not significantly affected by cultivation. Cultivation of wetlands significantly affected TDS, TSS, conductivity, Na, Ca. There was no significant effect of seasons on all the properties of water quality. Most of the water properties significantly differed among river systems with the exception of conductivity, Mg, Na, Ca, Fe and NO3-.

Future research should consider processes that lead to increase in the amounts of Na and Cd in soils and water samples of cultivated wetland and the pattern of change of wetlands to other land uses and the rate of change of quantitative soil and water properties.

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