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Threats of Land Use Changes on Wetland and Water Areas of Murang'a County, Kenya

Benson M. Mwangi*

Department of Physical and Biological Sciences, Murang'a University of Technology, P.O Box 75-10200, Murang'a Kenya
*Corresponding author: bmmwangi@mut.ac.ke

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Abstract Globally, wetlands have declined in area by over 50% since 1900, due to changes in land-use patterns, converting them into farmlands, human settlements, urban centers, and infrastructure development. Land-use changes also impact negatively on the water area (streams, rivers, lakes, reservoirs, and sea) of an area. In this study, the threats of land use changes on wetland and water areas in Murang'a County, Kenya, were assessed, in a bid to understand the main causes for the rapid decline in wetland and water areas in the County. Landsat images of 2001 and 2018 were analyzed using a supervised classification technique to produce Land-use maps in ArcGIS and detect associated changes. Between 2001 and 2018, the wetland area in Murang'a County declined by over 48% while the water area declined by over 25%. Bare-soil/built-up area posed the greatest threat to the conservation of wetlands in the County, taking up 161 ha of the wetland area during the period. The growth of woody shrubs posed the greatest threat to the loss of water areas taking up 152 ha of the water area during the period. Mean total threats facing wetlands differed significantly from mean total threats facing water areas in the County (t = 0.682; $p<0.001$). It is concluded that wetland and water areas are faced with similar human-induced land use threats but at varying magnitudes. It is therefore critical that specific regulatory legal and policy structures be urgently instituted to curtail further wetland and water area losses.

Keywords: *Hydrarch succession, encroachment, wetland vegetation*

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1. Introduction

Wetland loss due to land-use changes continue to be a major global concern due to its negative impacts on potable water supply. Before the ratification of the Ramsar Convention (the Convention on Wetlands of International Importance) in 1971, drainage and destruction of wetlands were common practice accepted and encouraged by certain governments [1]. The ratification of the Ramsar Convention, however, paved the way towards curtailing the trends of wetland overexploitation, drainage, and conversion, thus saving them from near extinction [2]. Consequently, knowledge of the importance of wetlands has improved immensely since then, although in many rural communities, particularly in developing countries such as Kenya, understanding of the sensitivity and fragility of the wetland ecosystems is still considerably low and many still view them as reservoirs for disease-causing organisms [3].

Over the years, various definitions of wetlands have been coined, most of which are broad requiring thorough interpretation before application. [4] defined wetlands as lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is covered by shallow water. [5] defines wetlands as areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, including areas of marine water, depth at which at low tide does not exceed six meters. Wetlands are highly valuable ecosystems due to their ecologic, economic, and cultural values.

Despite their values, however, undesirable anthropogenic activities continue to disrupt wetland ecological characteristics through degradation and eventual loss of entire wetland ecosystems. Wetland loss is defined by [6] as the loss of wetland area due to conversion of wetland to non-wetland areas as a result of human activities. Wetland degradation, on the other hand, is defined as the impairment of wetland function as a result of human activities (6). Due to their many ecosystem values and the threats to their ecological integrity, wetlands continue to attract much attention globally, with more emphasis and efforts being put towards their restoration, conservation, protection, and wise use [7].

Wetland loss is attributed to the misconceptions by dwellers in their adjoining areas and government institutions mandated to safeguard the well-being of wetland ecosystems. Historically, wetlands were perceived as *unexploited wastelands* [1], whereby value was placed upon their potential to be reclaimed and used for more productive purposes including agriculture, settlement, and industrial development [8].

Kenyan wetlands cover an area of up to 4% of the total landmass, which increases to about 6% during the rainy seasons [9]. These wetlands face threats from encroachment by riparian communities for the expansion of agriculture, industrial development, urban development, pollution, and invasive species. For example, the Tana River Delta, which is a wetland of international importance due to its high biodiversity has been severely threatened by large-scale commercial land use activities including agriculture, mining, industrialization, and hydropower generation [10]. Elsewhere, papyrus wetlands around the Lake Victoria Basin and other inland water bodies have been severely destroyed through encroachment by the riparian communities [11,12]. Consequently, the change in land use in the upper reaches of important catchment areas has had negative impacts on the wetlands of the Lake Victoria Basin such as a reduction in size due to the drying up of springs that were the main source of water.

Murang’a County is one of the counties in Kenya that is well endowed with wetland resources. The County is the main supplier of water to Nairobi, the capital city of Kenya, and also Thika, which is an industrial hub. During the last three decades, however, wetlands in the County have been severely degraded, mainly through conversion to agriculture and settlement [13]. Although some studies have been conducted on the effect of land-use changes on wetland ecosystems in the County, none have been conducted to identify the main drivers of the land-use change. This paper assessed the effect of land-use changes on the wetland and water areas to determine the current status of wetland conservation in the County.

2. Materials and Methods

2.1. Description of Study Area

Murang’a County is located in central Kenya at latitudes of 0° 34' S and 1° 7' S and longitudes 36° E and 37°27' E (Figure 1). The western boundary of the County cuts through the Aberdare forest at an altitude of 3353 m above sea level (asl), with the eastern part extending into lowland areas to a minimum of 914 m asl. It is one of the five counties in the Central Region of the Republic of Kenya and occupies a total area of 2,558.8 km^2. It is bordered to the North by Nyeri, to the South by Kiambu, to the West by Nyandarua, and to the East by Kirinyaga, Embu, and Machakos counties. The County is approximately 50km from Nairobi, the capital city of Kenya.

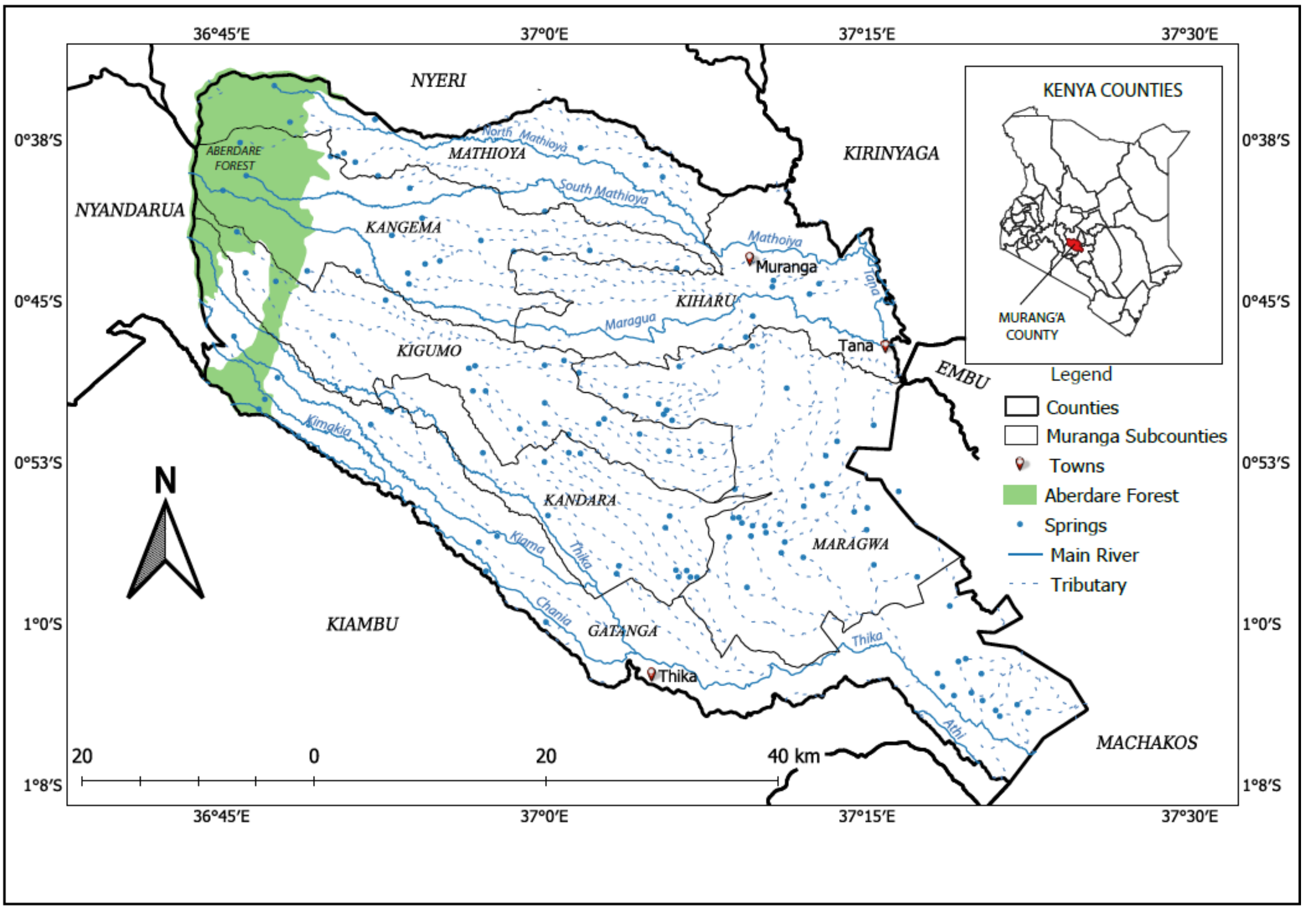

Figure 1. Location of Murang’a County, Kenya, showing the extensive wetland ecosystems occurring in the County

The County experiences a bi-modal rainfall with short rains from October to December and long rains from March to May. The County is divided into three climatic zones according to altitude. The upper zone extends from 1800 m to 2220 m asl, with the upper part marking the edge of the Aberdare forest. The upper zone is mainly characterized by tea growing, although other subsistence crops such as maize, vegetables, and dairy farming are also practiced. Annual rainfall at this zone averages 1800 to 2000 mm. The middle zone extends from 1400 to 1800 m asl, with annual rainfall ranging from 1400 to 1600 mm. Crops grown in the zone include coffee mixed with subsistence crops such as maize, bananas, beans, and vegetables, with low-level zero-grazing being practiced. The lower zone extends from 900 to 1400 m asl, with annual rainfall averaging below 900mm. Commercial agriculture, consisting mainly of pineapples, dairy farming, fruits, vegetables, french beans, and plantation forests of eucalyptus is practiced [14].

Soil types in the County differ from one zone to another, with the upper zone being largely dominated by volcanic ash [15]. Soils in the middle zone are largely dominated by nitosols, which are well-structured, nutrient-rich clay soils. Soils in the lower zone are mainly dominated by deep, strongly leached poor clay soils of the ferrosol category [15].

2.2. Data Collection

Data was collected using remote sensing imagery, which according to [16], are economical to use and can allow observation of large areas simultaneously. For that reason, the method has become a common research tool in various fields such as environmental monitoring and resource survey [17]. Ground truthing was conducted to relate image data to real features on the ground. The ground-truthing was also useful in the calibration of the remote sensing data and aided in its interpretation and analysis. Ground truthing data was used to verify land-use changes relative to the satellite map for 2018. In total, 10 land-use types were identified during the field surveys.

Satellite data consisted of multi-spectral data acquired by Landsat ETM+ for February 2001 and Landsat OLI for February 2018 (Table 1). These images were acquired during the dry season when the cloud cover was limited thus enhancing imaging quality and image clarity at a spatial resolution of 30m.

2.3. Image Pre-processing and Classification

Satellite image data was first pre-processed to reduce geometric distortions, atmospheric errors, and radiation distortions. Landsat ETM+ and Landsat OLI data were pre-processed in ENVI for radiation calibration and atmospheric correction. A maximum-likelihood algorithm was then used for supervised classification in which a pixel was selected as representative of the land-use class occupying the largest area in the pixel. The ArcGIS software, which is a spatial analysis technology, was used to obtain changes in wetland and water areas between 2001 and 2018. Using the land-use change data, a change matrix was constructed to illustrate how various land-use systems (threats) encroached onto wetland and water areas in 2018. To examine whether wetland and water areas were subjected to similar threats, in terms of magnitude and impact, a two-tailed *t*-test was conducted to test the hypothesis that there was no statistically significant difference between the mean total number of threats facing the wetland and the water areas in the County.

Table 1. Geospatial datasets used in the study

S/NO	Satellite Imagery	Date	Spectral resolution	Spatial resolution	Source
1	Landsat ETM+	25/02/2001	Band 7	30 m	USGS
2	Landsat OLI	27/02/2018	Band 5	30 m	USGS

3. Results

Analysis of LULC maps of 2001 (Figure 2) and 2018 (Figure 3), extracted from remote sensing data, showed that wetlands in Murang'a County declined by 379 ha between 2001 and 2018, representing a decline of 48.4%. During the same period, the water area decreased by 580 ha, a decline of 25%. Between 2001 and 2018, wetland and water areas were lost due to changes in various land-use types (Table 2). Out of the 379 ha of wetland area lost between 2001 and 2018, 161 ha were converted into bare-soil/built-up area, 15 ha to grassland, 66 ha to other cultivated areas, 39 ha was drained for agricultural production while 2ha converted to water area and 96 ha to woody shrubs. Out of the 580 ha of water area that was lost in the same period, 128 ha was converted to bare-soil/built-up area, 4 ha to forest, 128 ha to grassland, 18 ha to tea plantation, 24 ha to coffee plantation, 152 ha to woody shrubs, 69 ha to other cultivated areas, 45 ha to agricultural plantations, and 12 ha to wetlands. A t-test analysis indicated that the difference between the mean total number of threats facing wetlands in the County and the mean total number of threats facing the water area was highly significantly different ($t = 0.682$; $P < 0.001$).

Table 2. A Land use change matrix showing the transformation from Water Area and Wetlands to other Land uses between 2001 and 2018

Land-use Class 2001	Land-use Class 2018	Area (ha)
Wetland	Bare soil/built area	161
	Water area	2
	Grassland	15
	Other Cultivated areas	66
	Agricultural Plantation	39
	Woody Shrubs	96
	Tea Plantation	0
	Coffee Plantation	0
Total Wetland Lost	forest	0
	379	
Water Area	Bare soil/built area	128
	Wetland	12
	Grassland	128
	Other Cultivated areas	69
	Agricultural Plantation	45
	Woody Shrubs	152
	Tea Plantation	18
Total Water Area Lost	Coffee Plantation	24
	forest	4
	580	

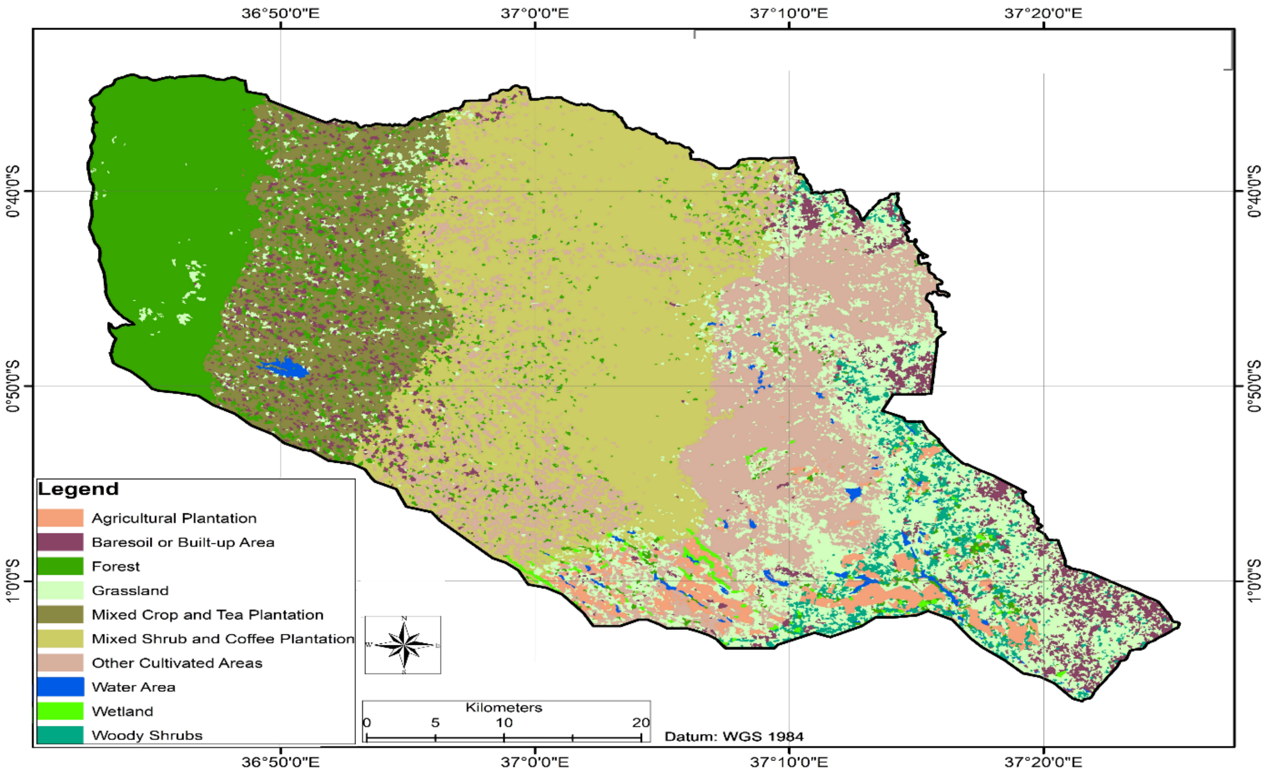

Figure 2. Murang'a County Land Use/ Land Cover Map 2001

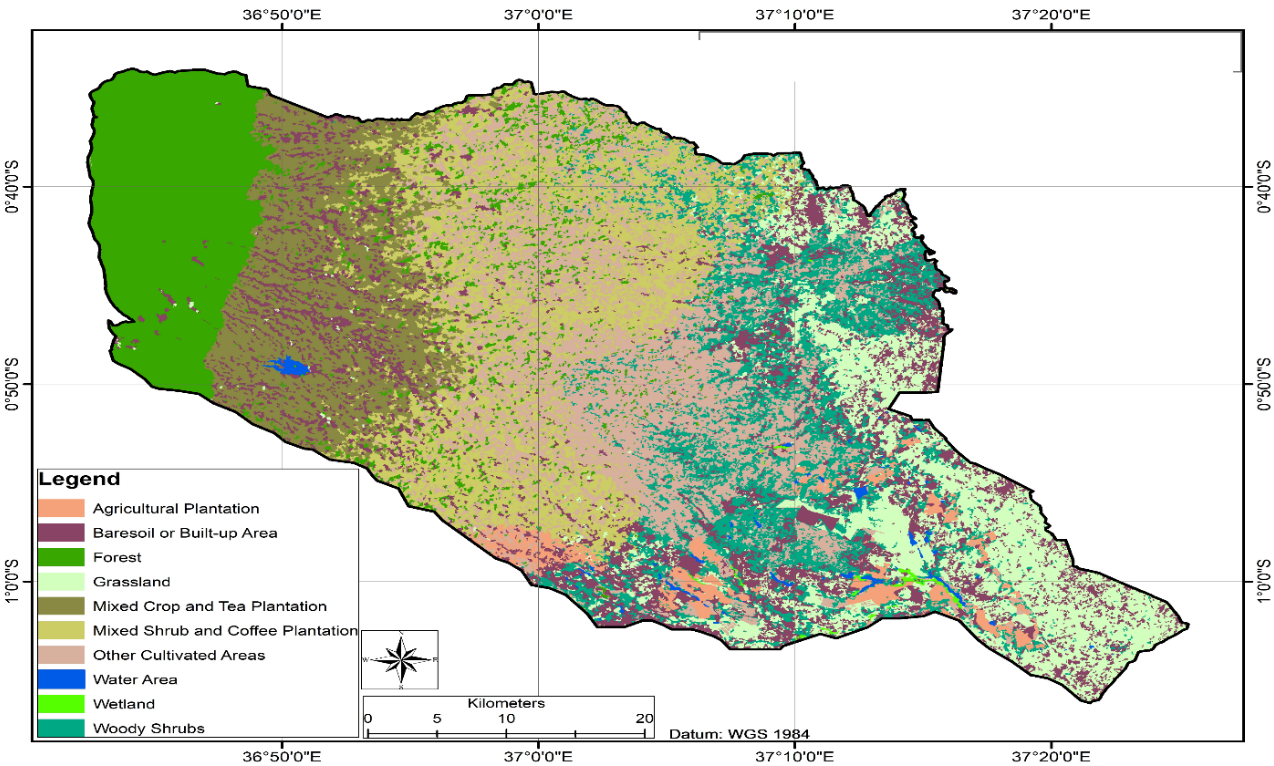

Figure 3. Murang'a County Land Use/ Land Cover Map 2018

4. Discussion

Increasing bare-soil/built-up area was the main threat facing the conservation of wetlands in Murang'a County between 2001 and 2018. This land-use type mainly consisted of settlements, infrastructure development, and the growth of urban centers. According to [18], increasing areas of settlement and urbanization impact directly on wetlands by draining them for purposes of developing the land, and also indirectly through increased stormwater and pollutants generated by land development. The development of wetlands leads to stress among plant and animal communities in those wetlands. [19] noted that wetlands that are crossed by major roads exhibit signs of drainage since they appear smaller than they were before the construction of the roads.

The expansion of bare-soil/built-up area is also responsible for the decline of the water area in the County. About 128 ha of water area was converted to bare-soil/built-up area between 2001 and 2018. Construction of roads, hydropower plants, bridges, and water intake points across and on the major rivers has led to huge disruptions of the rivers in the County [14]. During the construction of the Northern Collector Tunnel in the Maragua watershed, numerous water diversions, weirs, and related intake hydraulic structures were constructed at Maragua, Gikigie, and Irati Rivers to allow room for construction work. A study done by [20] deduced that river diversions not only alter the downstream water quality but also affect channel geomorphology and reduce floodplain biological productivity over the long term.

Woody shrubs encroachement emerged as a threat to the well-being and existence of wetlands in the County. About 96 ha of what was originally covered by wetland in 2001 had been encroached by woody shrubs in 2018. The encroachment of woody shrubs is considered a natural part of hydrarch succession [21]. However, human-induced changes such as lowered water tables, nutrient influx, and disturbances can create favorable conditions allowing woody colonization and growth [22]. On the other hand, 152 ha of the water area were encroached by woody shrubs in 2018. Encroachment of woody shrubs along waterways is caused by poor watershed management leading to alteration of stream ecology and hydrology in ways that accelerate the invasion and expansion of non-native woody species [23]. As the woody shrubs spread, ecohydrological impacts such as drops in the water table and reduced water yield downstream become prevalent [24].

Agricultural activities increased steadily from 2001 to 2018 leading to a decline in wetland cover and water area in the County where activities towards drainage of wetlands and clearance of wetland vegetation for agriculture dominated. Cultivated areas encroached on 66 ha of wetland, while agricultural plantations also expanded encroaching on 39 ha of wetland. According to [25], loss of wetland vegetation through clearance and drainage of wetlands for agricultural purposes causes a major shift in the ecological character of a wetland, as well as on its coverage. Water bodies have also been negatively impacted by the expansion of agriculture in the County. For instance, tea farming encroached on 18 ha, while coffee farming encroached on 24 ha of the County's water area. Additionally, cultivated areas encroached on 69 ha, and agricultural plantations encroached on 45 ha of the water area. [26], noted that increased agricultural activities within water catchment areas pose serious threats such as water pollution from agrochemicals and encroachment on wetlands.

Wetlands and water areas are faced with threats from similar land-use changes, however, the magnitude and impact of these changes differ between wetland and water areas. This corresponds with the situation in the Czech Republic [27], where the temporal change of wetland and water areas differed, with still waters decreasing gradually between 1780 and 2010, and wet meadows disappearing almost completely during the study period.

5. Conclusion

Bare soil/built-up area poses the greatest threat to wetlands in Murang'a County, while the major threat to the water areas of the County emanates from the encroachment of woody shrubs. The Baresoil/built-up area is composed of human settlements and cleared land, while woody shrubs mainly comprise non-native woody species invading the water areas. The land-use changes are mainly caused by increased human activities within wetlands and water areas. It is evident from this study that wetland and water areas are faced with threats from similar land-use changes, however, the magnitude and impact of threats in wetlands and water areas vary from one land-use change to another. It is therefore strongly recommended that specific policy and legal structures be instituted to curtail further loss of wetland and water areas

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References

[1] Daryadel, E. & Talaie, F., "Analytical-Study-on-Threats-to-Wetland-Ecosystems-and-their-Solutions-in-the-Framework-of-the-Ramsar-Convention". 2018.

[2] MEA (Millennium Ecosystem Assessment), *Ecosystems and human wellbeing*. Synthesis. Washington, DC: Island Press. 2005.

[3] Keche, A., Ochieng, G., Lekapana, P., and Macharia, G. (2007). Status of Wetlands in Kenya and Implications for Sustainable Development. *Environment and Sustainable Development*.

[4] Cowardin, L.M., Carter, V., Golet, F.C., and LaRoe, E.T, Classification of wetlands and deepwater habitats of the United States. U.S Fish & Wildlife Service Publ. FWS/OBW-79/31. Washington, DC. 1979.

[5] Ramsar Convention Bureau, *Ramsar Handbooks for Wise Use of Wetlands*. Ramsar Convention Bureau, Gland, Switzerland, 2000.

[6] Moser, M., Prentice, C. and Frazier, S., "A Global Overview of Wetland Loss and Degradation, Proceedings of Ramsar COP6" Brisbane, 1996, Vol. 10/12, Technical Session B at p. 21.

[7] Jeelani, N., Yang, W., Xia, L., Zhu, H. L., &An, S., "Ecosystem threats and management strategies for wetlands in China". *Marine and Freshwater Research*, 71, 1557-1563, 2020.

[8] Juliano, K. & Simonovic, S.P., "The Impact of Wetlands on Flood Control in the Red River Valley of Manitoba", Final Report to International Joint Commission, Natural Resources Institute, University of Manitoba, Winnipeg, Manitoba, 1999, pp.8.

[9] Oduor, F.O., Raburu, P.O., &Mwakubo, S., "To Conserve or convert wetlands: evidence from Nyando Wetlands, Kenya". *J. Dev. Agric. Econ*. 7(2): 48-54, 2015.

[10] Nunow, A. A., *The Dynamics of Land Deals in the Tana Delta, Kenya*. LDPI: 2017, 1-27.

[11] Morrison, E.H.J., Upton, C., Odhiambo-K'Oyooh, K. and Harper, D.M., Managing the Natural Capital of Papyrus within Riparian Zones of Lake Victoria, Kenya". *Hydrobiologia*, 692, 5-17.

[12] Twesigye, C.K., Onywere, S.M., Getenga, Z.M., Mwakalila, S., & Nakiranda, J.K., "The impact of land use activities on vegetation cover and water quality in the Lake Victoria watershed". *The Open Environmental Engineering Journal*. 4, 66-77, 2011.

[13] Muema, J.M., Kaluli, J.W., Gathenya, J. M. and Mwangi, B.M., “Evaluation of Wetland Loss in Maragua Watershed, Murang’a County, Kenya”. *Journal of Sustainable Research on Engineering* 4 (4), 160-170, 2019.

[14] Murang’a County Integrated Development Plan, 2018. https://cog.go.ke/media-multimedia/reportss/category/106-county-integrated-development-plans-2018-2022?download=311:murang-a-county-integrated-development-plan-2018-2022. Retrieved March 18, 2020.

[15] FAO. (2000). Land cover classification system: Classification concepts and user manual. Food and Agriculture Organization of the United Nations. Rome.http://www.fao.org/3/x0596e/x0596e00.htm. Retrieved February 10, 2020.

[16] Sun, X., Lu, M., and Ren, Z., “Dynamic changes and sensistivity of water Area of Huixiankarst wetland” *earth and environmental science 512*, 2020. 012033.

[17] Zhang, Y., & Wang, D.Y., “Land use Types Dynamic Changing analysis based on remote sensing data in Xianlin district of Nanjing”. *Journal of Nanjing Normal University (Engineering and Technology Edition*), 17, 79-85, 2017.

[18] Ehrenfeld, J.G.& Schneider, J.P,. “*Chamaecyparisthyoides* Wetlands and Suburbanization: Effects on Hydrology, Water Quality and Plant Community Composition.” *J. Applied Ecology,* 28, 467-490, 1991

[19] Forman, R.T., & Deblinger, R.D., “The Ecological Road-Effect Zone of a Massachusetts (U.S.A.) Suburban Highway”. *Conservation Biology,* 14(1), 36-46, 2000.

[20] Fantin-Cruz, I., Pedrollo, O., Girard, P., Girard, P., Zeilhofer, P., & Hamilton, S.K., “Changes in river water quality caused by a diversion hydropower dam bordering the Pantanal floodplain”. *Hydrobiologia* 768, 223-238, 2015.

[21] Mitsch, W.J., Gosselink, J.G., *Wetlands.* 3rd ed. Van Nostrand Reinhold, New York. 2000.

[22] Gaudet, C.L. &Keddy, P.A., “Competitive performance and species distribution in shoreline plant communities: a comparative approach”. *Ecology*, 76, 280-291, 1995.

[23] Huddle, J., Awada, T., Martin, D., Zhou, X., Pegg, S., & Josiah, S., “DO INVASIVE RIPARIAN WOODY PLANTS AFFECT HYDROLOGY AND ECOSYSTEM PROCESSES?”. *Great Plains Research,* 21(1), 49-71, 2011. Retrieved March 10, 2021, from http://www.jstor.org/stable/23779968.

[24] Scott, R.L., Huxman, T.E. Williams, D.G. & Goodrich, D.C., “Ecohydrological impacts of woody plant encroachment: seasonal patterns of water and carbon dioxide exchange within a semiarid riparian environment”. *Global Change Biology*, 12, 311-24, 2006.

[25] Macharia, J., Thenya, T., and Ndiritu, G., “Management of highland wetlands in central Kenya: The importance of community education, awareness and eco-tourism in biodiversity conservation”. *Biodiversity,* 11, 8590, 2010.

[26] Kithiia, S.M., “Land use changes and their effects on sediment transport and soil erosion within the Athi river drainage basin, Kenya”. In: *Human Impact on Erosion and Sedimentation (proceedings of Rabat Symposium S6*, April 1997. IAHS Publ. No. 245, 1997. 145-150.

[27] Šantrůčková, M., Demková, K., Weber, M., Lipský, Z., and Dostálek, J., “Long term changes in water areas and wetlands in an intensively farmed landscape: A case study from the Czech Republic”. *European Countryside.* 9. 132-144, 2017.