Impact Analysis of Mining on Wetland Transformation in Rwanda

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Abstract

Inappropriate management of produced mine wastes, from mining activities, has created serious transformation of wetlands in many countries of the world including Rwanda. In this study, Geographic Information Systems (GIS) and Remote Sensing (RS) technologies were used to detect and evaluate Where, When, What, Why, and How much of an impact results from the mining activities on wetland. Unsustainable mining, with HAVILLA mining company, has led to the encroachment of diverse wetland vegetation, in Mwogo wetland, which increased gradually during development and post development stages of mining activities due to the pressure for agricultural land expansion and shift. Mwogo wetland also experienced the increase of much siltation in Mwogo River that has led to the River bifurcation, dewatering and water diversion. Gashyenzi playground, Rurangazi market ground and cows 'stables ground were converted into plots of farmland due to the severe floods driven by degradation of Mwogo river channel. Rurangazi main bridge was collapsed because of Stagnation of water blocked nearby. Water for irrigation and other uses has become scarce in that area because of water pollution. Since 2013, MAWARID mining company has employed the security keepers to protect Nyamagana mining site from intruders who mine illegally and damage wetland, in turn. In 2016, the radical terraces were made around the boundary of the wetland to minimize the additional sedimentation and flooding in the wetland. The major reasons for these damages were identified to be inability of the mining company to monitor and enforce compliance with environmental regulations, and the lack of institutional frame work for wetland protection and management. Short term, medium term and long term actions, for wetland rehabilitation, were proposed as solutions and forwarded as recommendations.

Key words: Mining, wetland, Geographic Information Systems (GIS) and remote sensing (RS).

1. Introduction

Mining is the process of extracting a naturally occurring material from the earth to derive a profit (Nsabimana, 2018). It is also defined as the process or business of working mines (Perks, 2016). Mining has five stages which are the prospecting, exploration, development, exploitation, and reclamation (MINIRENA, 2010).

However, the mining industry has potential contribution to the economic development; it has also the environmental issues including transformation of wetland resources at the same time (Sjoblom, 2003. Mining activities generate effluent containing a number of pollutants, which adversely alter the quantity and quality of wetland resources that often cause significant pollution (Jucan, 2016).

Wetlands are valuable to humans due to their notable ecosystem functions and services, such as protecting biodiversity, adjusting hydrology and climate, and providing important habitats, products, and tourism resources (Jacob & Otte, 2003). Intensive human activities and climate change worldwide, however, have led to extensive wetland loss. Such losses also have caused pronounced ecological consequences including floods, biodiversity loss, coastal damage, water quality degradation, and carbon sequestration decline. Therefore, human efforts should respond to these wetland losses and associated negative consequences (Sjoblom, 2003).

The global extent of wetlands is now estimated to have declined between 64-71% in the 20th century, and wetland losses and degradation continue worldwide. Because of wetland losses and degradation, people are deprived of the ecosystem services that wetlands provide. Adverse changes to wetlands, including coral reefs, are estimated to result in more than US$ 20 trillion in losses of ecosystem services annually (Ramsar, 2000).

North Met project, for copper-Nickel in Canada in 2013, destroyed 912.5 acres of wetlands around the mine site, hence water pollution associated with sulphide mining, damages from land cover changes, and loss of habitat for animals and vegetation (Niu et al., 2013).

Due to mining operations, studies in several major catchments in South Africa reveal that between 35% and 60% of wetlands have been lost or severely degraded. This would affect the production and delivery of services derived from healthy wetland ecosystems and can exacerbate water quality and water security hazards with social stability and economic implications (Runciman, 2013).

In 2008, the Rwanda Environmental Management Authority conducted a national inventory and mapping of all wetlands, lakes, and rivers. The delineation and classification accuracy of the inventory, however, were quickly questioned as numerous inconsistencies were identified during the national wide land registration process that started 2 years later. These inconsistencies point to the fact that wetland bodies are changeable over time (REMA, 2011).

2. Materials and Methods

Study area description.

Nyamagana Mining site located in Nyanza district, with three mines, is the Mining concession near the township of Nyanza in Southern Province, Rwanda. It covers an area of approximately 40 ha, and it is highly prospective for Tantalum/ Nobium Mineralisation referred. This Mining concession is owned by both, Mawarid Mining Rwanda Limited acquired 85% share in the Havilla mines and Havilla itself. HAVILLA mining company had Nyamagana Mining Site before (2002 to 2012) then MAWARID mining Company took that site (2013 to now-June2020) for sustainable mining although the active mining has not started yet. The company has completed ground magnetic and gravity surveys to better define the extent on the pegmatite, this was then followed up with geological mapping, trenching and sampling (www.mawaridmining.com).

Nyamagana Mining site is connected to the Mwogo wetland, in Rurangazi cell, with streams Nyanza and Gasayo that are tributaries of Mwogo River. Mwogo wetland covers an area of 128 hectares, and is also located in 700 meters from Nyamagana mining site.

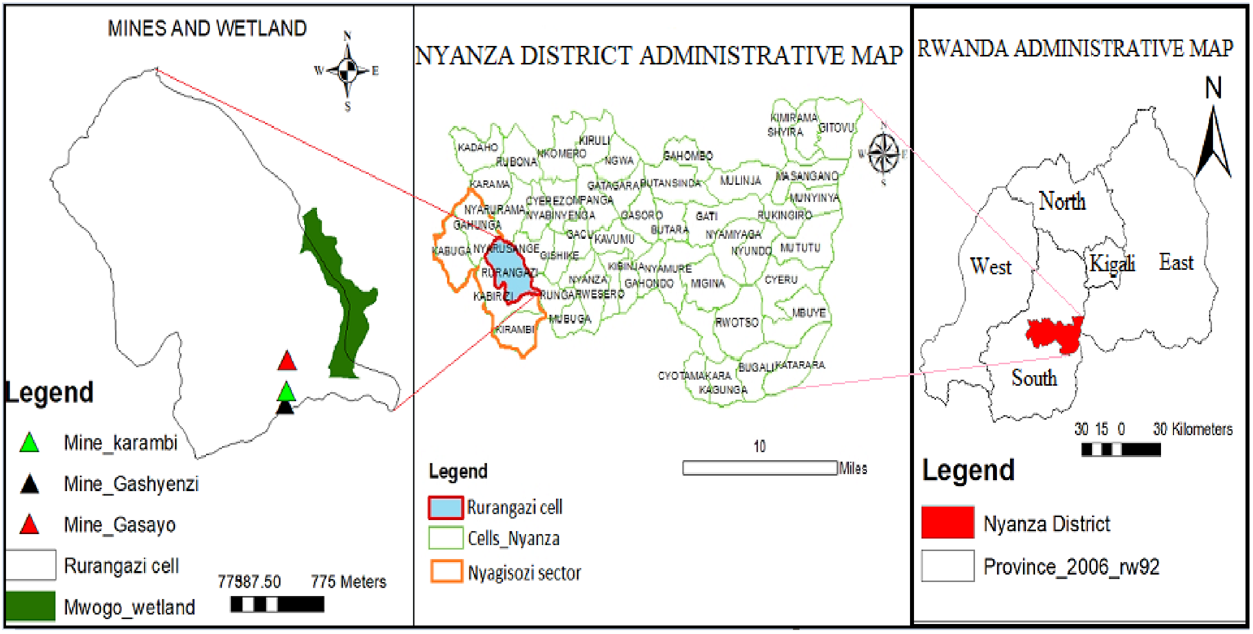

Figure 1: Geographical location of the case study.

Land use/cover types in the wetland.

Table1: Land use/ cover categories in Mwogo wetland

Land use/cover type	Description
Built-up land	Built-up consists of settlement, Rurangazi market, Rurangazi playground, Gashyenzi playground, and cows ‘stables for livestock.
Farming land	Areas of land prepared for growing crops. This category includes areas currently under crops and land under preparation. In details, this includes agricultural land, banana cultivation, sugar cultivation, and rice cultivation.
vegetation	Areas covered by Forest, papyrus, grasslands, shrubs, thickets and all naturally existing wetland plants.
Water bodies	Water bodies include Mwogo River, as natural channel, with its distributaries and streams Gasayo and Nyanza.

Source: Researcher (2020).

Approach for processing, analysis and interpretation of wetland transformation

To aid in generating indicators for impact analysis and understanding wetland transformation, satellite images, with high-resolution, from Google Earth pro have been used in this study to provide a critical data source for analysis of wetland use and cover transformation during different periods, including 2000, 2011, and 2020 (June). All images were geo-referenced and rectified to the Rwanda National Coordinate System-Universal Traverse Mercator (UTM) projection and Arc 1960 datum using ArcGIS 10.6 software. Geographic Information Systems (GIS), with ArcGIS 10.6 software, also provided an important approach to achieve digitizing, mapping and overlay analyses for Mwogo wetland visual interpretation.

3. Results and Discussions

Wetland structure before, during and after mining activities

To generate various indicators for Mwogo wetland transformation, land cover data sets in 2000, 2011 and 2020 (June) were obtained. In this process, high-resolution images from Google earth were used to detect the wetland use and cover change. In terms of time, this research was carried out to analyze the impact of Mining on Mwogo wetland since 2002 up to June 2020 but the years of 2011 and 2020 were selected because they were highly marked with the relatively considerable transformation in the wetland.

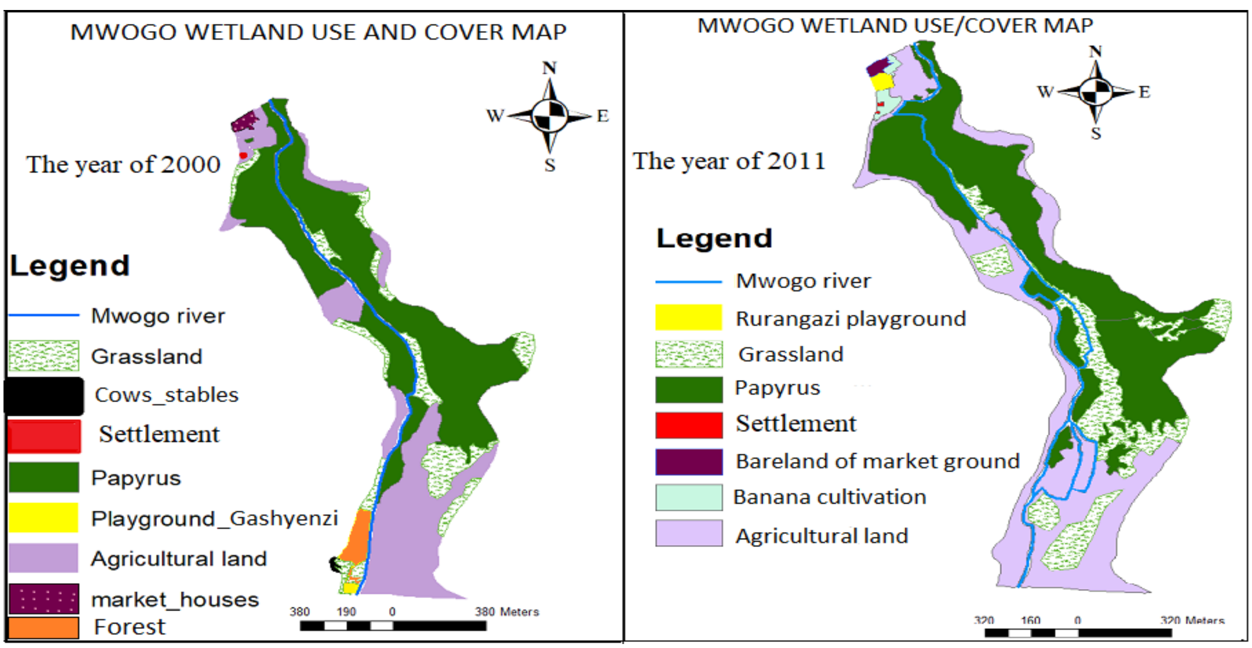

Figure 2: Mwogo wetland use and cover in 2000 and 2011.

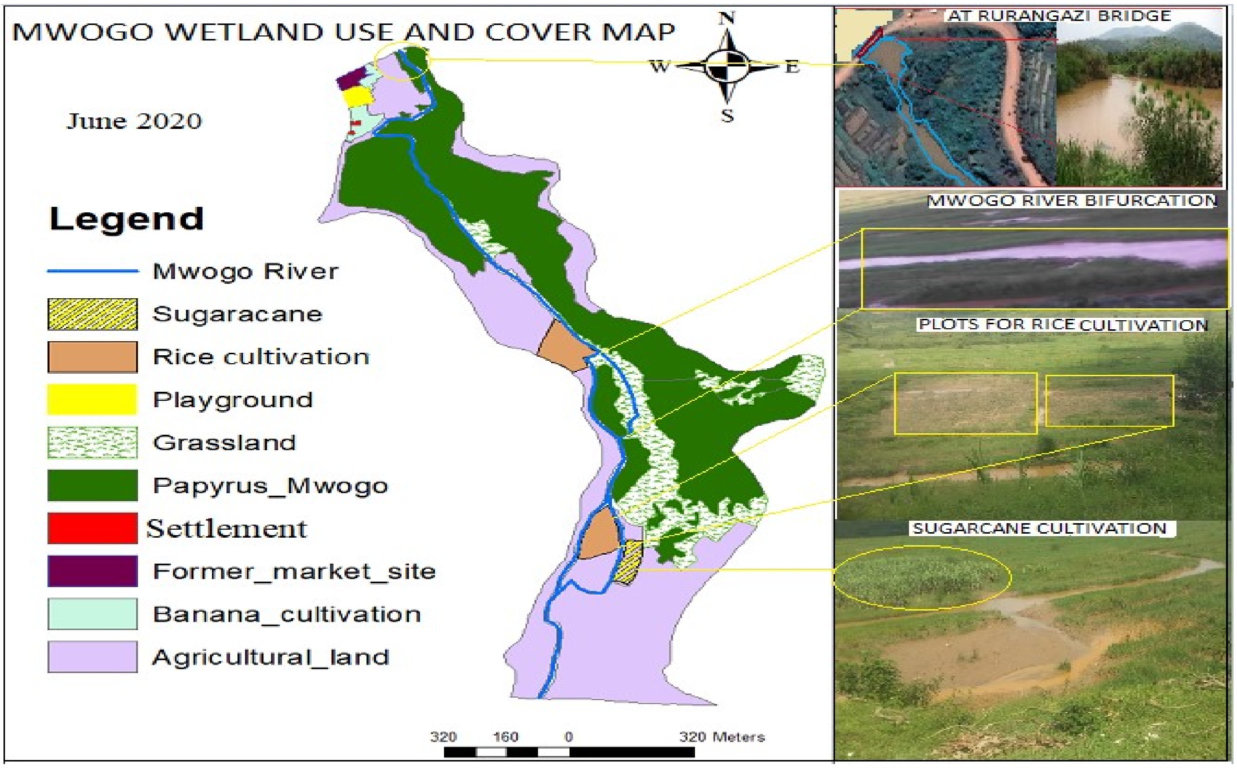

Figure 3: Mwogo wetland use and cover in June 2020.

Damages from the impact of Mwogo wetland transformation.

Wetland loss encroached upon by agricultural expansion and shifting.

Sediment-laden surface runoff typically originated as a sheet flow from Nyamagana mining site and collected in Gasayo and Nyanza streams as well as human-made conveyances led to the ultimate deposition of the sediment within wetland and have caused the built-up of thick layers of mineral fines to alter the use and cover of the wetland. Available land reserved for crop cultivation has become limited whereby the communities from the adjoining areas have destroyed an enormous area of papyrus for agricultural expansion and shift. The rhizomes of papyrus were even harvested to reduce the regeneration potential in Mwogo wetland. Papyrus covered 74.24 ha in 2000, 72.064ha in 2011 and 71.424 ha in (June) 2020 accounting for 58%, 56.3% and 55.8% respectively.

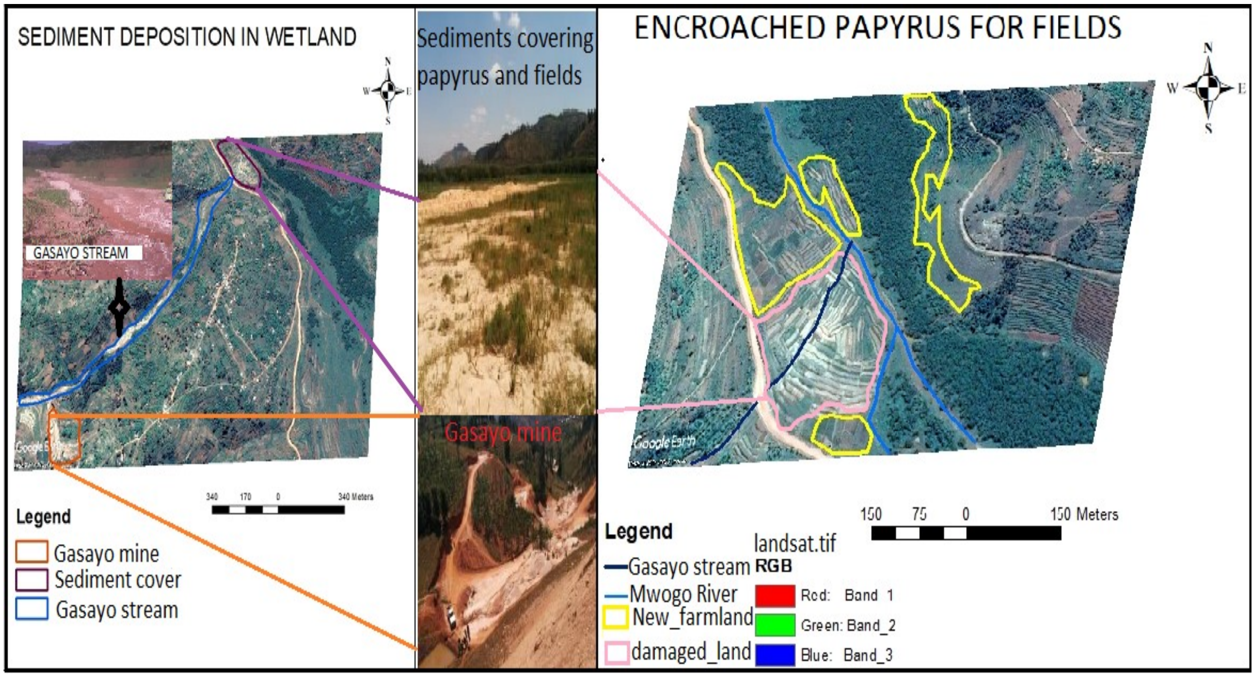

Figure 4: Sediment deposition and papyrus encroachment.

The total area of wetlands in Rwanda is approximately 278,000 ha of which, in 2009, 53% was used for cultivation. This accounts for 12% of the total cultivated land in the country. Farmers living in the uplands make use of the neighboring wetlands and generally plant similar crops in both up-and lowlands (REMA, 2011). Human encroachment on papyrus wetlands, for agricultural production, has been identified as an influence on streams flowing into Lake Victoria in Uganda. Sub catchments with papyrus wetlands up on which humans had encroached, had sediment yield values that were about three times larger compared to catchments with intact papyrus vegetation (Kansiime et al., 2007).

Cause and consequences of Stagnation of water due to blockage.

Due to much siltation accelerated by mining activities, frequent alteration in Mwogo river course and water levels has resulted into frequent conflicts between the wetland infrastructures bordering the wetland. Besides Gashyenzi playground and Rurangazi market ground converted into farmland due to the severe degradation as a result of erosion and deposition of mine wastes in the wetland, Rurangazi Bridge connecting three neighboring sectors (Nyagisozi, cyabakamyi and Rwabicuma sectors) was collapsed due to the stagnation of water blocked nearby. Water and siltation collapsed it gradually by wearing away the earth around and underneath the bridge piers.

Nowadays, the vehicles are not allowed to cross that degraded bridge.

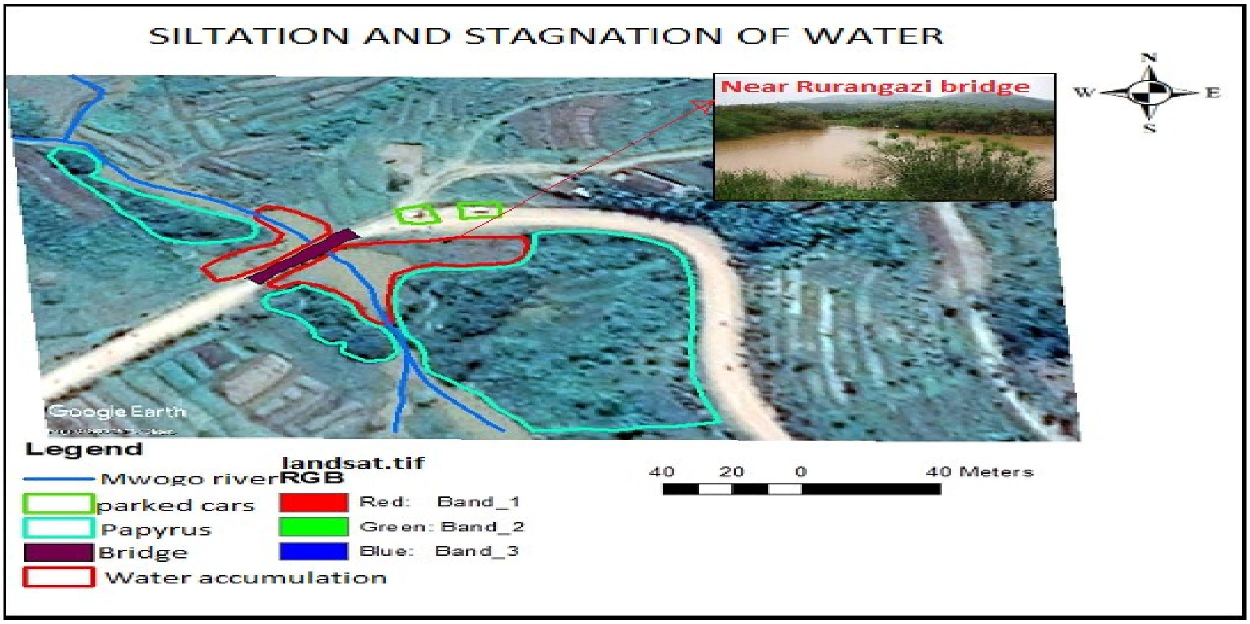

Figure 5: The collapse of Rurangazi Bridge due to the Stagnation of water.

When the river passes under a bridge, the high water levels smash the debris into the bridge. Floods dramatically increase the force and volume of water affecting the bridge, and the damage to sediments can cause a bridge to collapse immediately or even days or months later (Vanmaercke et al., 2014a). This is what happened to the Liftin Bridge, located on Robinsons Road. The water level has dropped to just below the bridge deck level. The silt deposition extends for approximately 60 m each side of the bridge and was up to 2m in depth. The material was soft, difficult to cross by foot and impassable for all vehicle types (Queensland Reconstruction Authority, 2011-2012).

River bifurcation, Water diversion and dewatering.

During development stage of mining activities, farmers have relocated and dewatered a small natural section of Mwogo River with a short section of created channel to favor agricultural practice in the reclaimed plots of farmland.

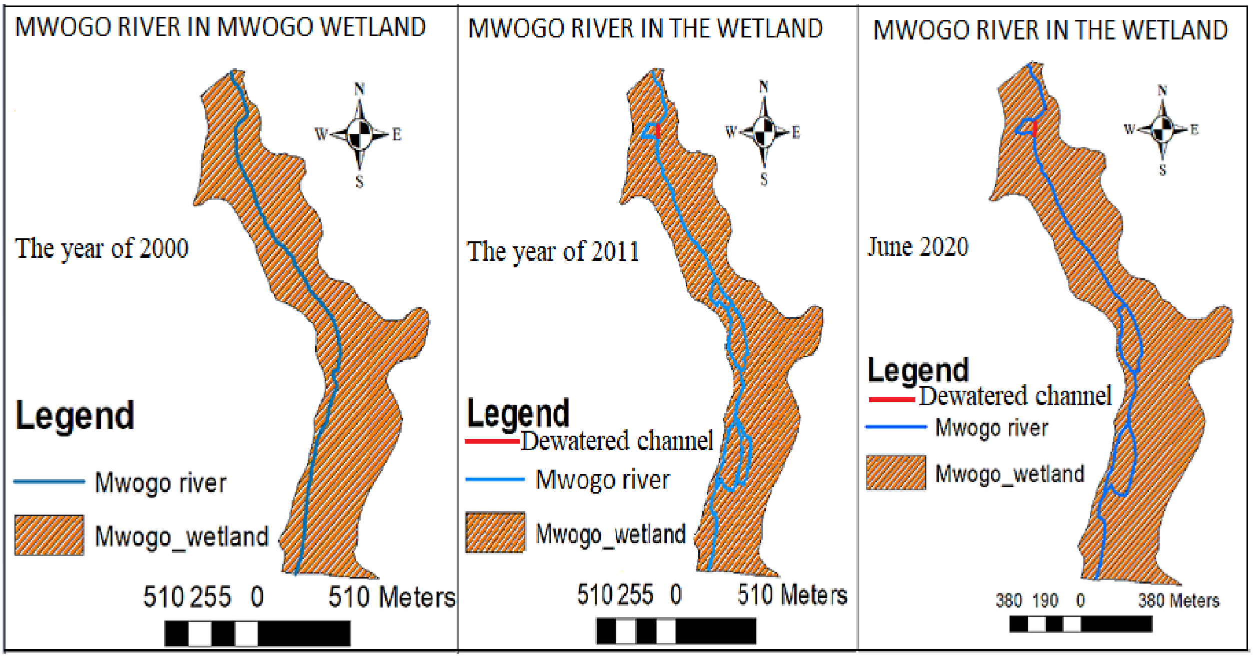

Figure 6: River bifurcation and water diversion in the Mwogo wetland.

River bifurcation occurs when a river flowing in a single stream separates into two or more separate streams (called distributaries) which continue downstream. River bifurcation may be temporary or semi-permanent, depending on the strength of the material which separates the distributaries. The Hase River in Melle, Germany divides into Hase River and Else river and has researched as natural phenomenon (Tomovic, 2006).

The term river diversion is commonly used to describe several of water out of channel, such as for irrigation or for inter-basin transfers. For example, the Chinese recently completed the South North water transfer, the world's largest water diversion. Fundamentally, a relocated channel replaces a natural section of a river with a short section of artificial (man-made) channel (Zedler & kercher, 2005).

Heavy siltation, severe flooding and crop failure.

As a result of excessive siltation within the wetland and the river channel, crop failure is a common occurrence during the rainy seasons. The droughts following those rains also cause crop failure. During active mining, the majority of farmers shifted their agricultural activities to upland fields where they have regained the wetland, for crop cultivation, after that Havilla mining company stopped mining activities. The cultivated plots of farmland in 2000 covered 43.52ha (34%), 33.664ha (26.3%) in 2011 and 51.84 ha (40.5%) in June 2020.

Figure 7: Siltation, flooding and crop failure.

However, Floods are somehow vital part of many ecosystems (including connectivity between rivers and their plains, bringing water and nutrient-rich sediment that produce fertile soils, habitats for birds, spawning grounds for fish and natural irrigation that provides lush pastures for livestock), Large floods can be very destructive and lead to damage to property, agricultural land and infrastructure and in the worst case, loss of life (Zedler & kercher, 2005).

Significance of mitigation measures

Below are some achieved rehabilitation efforts:

Protection of Nyamagana mining site from intruders.

Since 2013, Mawarid mining company has employed some local people and the reserve forces known as "Inkeragutabara" to prevent the intruders from mining illegally. Although some individuals mine illegally during the night, the water in the streams and the river were relatively clear for irrigation and some other uses. The local communities restarted to enjoy provisioning, regulating, cultural and supporting services from the wetland.

The people settling around Lubigi wetland system are both the actors and spectators of the associated environmental degradation challenges; it thus needs the population of this area to assume responsibilities in guiding and controlling its development to safeguard the environment with the help of responsible government institutions like NEMA and No Government Organizations (NGO's) in this same sector (Omagor & Barasa, 2018).

Mwogo wetland catchment restoration.

Mining activities have imposed great transformation to wetland ecosystems. In 2016, a buffer of 100m, around the wetland boundary, was leveled for radical terraces in order to minimize the additional disturbances through rapid surface runoff of rain water. As a result, the run-off capacity was controlled and this has somehow facilitated the farmers to reclaim the damaged plots of farmland, day by day.

Figure 8: Radical terraces around the boundary of Mwogo wetland.

Radical terraces have the potential of improving of farmers „livelihoods and increasing the resilience of a degraded environment including the wetlands. After establishing a terrace, a riser is shaped and grasses or shrubs/trees are planted soon after (RNRA, 2017).

4. CONCLUSION AND RECOMMENDATIONS

Based on Geographic Information system (GIS) and remote sensing (RS), the research detected and evaluated the cause and consequences of Mwogo wetland use and cover transformation. Mining, at Nyamagana site, is posing a very critical and significant menace to the Mwogo wetland health and nearby habitats, together with fauna and flora, and also micro fauna in river basins and for the water cycle. So, proper mitigation approach should be developed to improve and develop effective removal techniques. With Mawarid Mining Rwanda Limited, Industry is now doing its best to improve working conditions, abate pollution, and safeguard the environment by getting community involvement and increasing the level of awareness of the employees. The impacts of mining and other problems related with mine water management cannot be easily addressed over the short term and may have devastating consequences for more than just ecosystems. The hypothesis of the research was tested and then accepted whereby the Mwogo wetland was transformed intentionally by non-eco-friendly miners. Referring to some efforts made to rehabilitate Mwogo wetland; this wetland can't stand as a testimony of Rehabilitation efforts towards sustainable management of natural resources. The researcher proposed the strategies in order that some endangered wetland ecosystems provide relatively working conditions for local communities' livelihoods. This research thereby recommended that through Environmental Impact Assessment should be done before any site could be used for mining activities and Illegal mining should be stopped. Various administrative entities should validate the rehabilitation plan with occasional field visit aiming of assessing the field practability of the plan at every stage. Other strategies include the construction of sediment traps technologies upstream to the reservoir plus development of mechanism to remove periodically the retained sediment, relocation of all Mwogo river outlets to the natural river channel, buffer zones by planting grass, and trees around the wetland as well as bamboos on the main Mwogo river, and local community training and capacity development toward eco-friendly agribusiness in the Mwogo wetland.

Study limitation

The data yields were important as descriptive information about the impact analysis of mining activities on wetland transformation in Rwanda, the case study of Nyamagana mining site in Nyanza district. Although there is no reason to doubt the validity of the findings, the researcher addressed to further researchers to assess the impact of mining on water quality in this study area to analyze its damages.

BIBLIOGRAPHY

1. Abebe GA. (2013). Quantifying urban growth pattern in developing countries using remote sensing and spatial metrics: A case study in Kampala, Uganda. University of Twente Faculty of Geo-Information and Earth Observation (ITC).
2. Adamus, A. (2002). Review of the use of nitrogen in mine fires. Mining technology: IMM transactions section A111 (2): 89-98.
3. Adams, P.R., E.J.Clairain, R.D.Smith, and R.E. young. (1987). Wetland Evaluation Technique (WET). Technical report y-87. Vicksburg, MS:U.S.Army Engineer Water-ways Experiment station
4. Andrew, G., &Masozera, M. (2010). Payment for ecosystem services and poverty reduction in Rwanda. Journal of

sustainable development in Africa, 12(3), 122-139.

5. Berbier EB. (1994). Valuing environmental functions-tropical wetlands. Land Econ 70(2):155-73
6. Bertoldi, W., and M. Tubino. (2007). River bifurcations: Experimental observations on equilibrium configurations, *Water Resour. Res*., 43, doi: 10.1029/2007WR005907.
7. Brinson MM, Malvarez AI. (2002). temperate freshwater wetlands: Types, status, and threats. Environ conserv29 (2):115-33.
8. Cherry, J. A. (2011). Ecology of Wetland Ecosystems: Water, Substrate, and Life. Nature Education Knowledge 3(10):16.
9. Gilbert-Norton L, Wilson R, Stevens JR,Beard KH. (2010). A Meta-Analytic Review of Corridor Effectiveness. Conserv. Biol.24 (3):660-668.
10. Government of Rwanda (NISR, RMB). (2019). *Natural Capital Accounts for Mineral Resource flows*, Version 1.0. Kigali.
11. Hoglund, L.O. (2003). EU-Towards a New mines Directive-Main priorities Kemakta Konsult ab.
12. Hopkinson Cs, Vallino JJ. (1995). The relationships among man'activities in watersheds and estuaries. A model of runoff effects on patterns of estuarine community metabolism. Estuaries 18(4)598-621.
13. https://www.mawaridmining.com. Accessed on 23 April 2020.
14. https://www.nyanzadistrict.gov.rw. Accessed on 20 June 2020.
15. https://www.usgs.gov. Accessed on 18 May 2020.
16. Jacob, D.L. & Otte, M.L. (2003) Conflicting processes in the wetland plant rhizosphere: metal retention or mobilization? Water, Air and Soil Pollution Focus.3, 91-104.
17. Jucan, V,Dumitrescu,A.M., Iordan, A.R.and plamarub, M.N. (2016). Influence of Heavy Metals on the Environmental from Tarnita Mining Area. Acta chemical IASI, 24(1):1-19.
18. Kansiime, F., Saunders, M.J., Loiselle, S.A. (2007). Functioning and dynamics of wetland vegetation of Lake Victoria: an overview. Wetl. Ecol. Manag. 15 (6), 443–451.
19. Keddy, P.A. (2000). W*etland Ecology: Principles and Conservation*. Cambridge University Press, Cambridge, 614 pp.
20. Nabahungu N.L, &Visser, S.M. (2011b). Contribution of wetland agriculture to

farmer's livelihood in Rwanda. Ecological Economics.

21. Ministry of Natural Resources (MINIRENA) (2010). *Mining Policy*. Transforming Rwanda's Mining Industry. Kigali-Rwanda. Pp.3.
22. Niu JY, Zou YA, Yuan X, Zhang B, Wang TH. (2013). Water bird distribution patterns and environmentally impacted factors in reclaimed coastal wetlands of the eastern end of Nanhui County, Shanghai, China.
23. Nsabimana, E. (2018). *New law will help drive investor appetite for mining*. New Times. Retrieved from https://www.newtimes.co.rw/news/new-law-will-help-drive-investor-appetite-mining-gatare. Accessed April 2020.
24. Omagor, J., & Barasa,B.(2018).Effects of Human wetland encroachment on the degradation of Lubigi wetland system, Kampala city Uganda.
25. Perks, R. (2016) Re-framing the nature and success of the "post-conflict" mineral reform agenda in Rwanda. *The Extractive Industries and Society, 3*(2): 329–339.
26. Ramani, R.v. & M.L. Clar. (1978). User's Manual for Pre-mining Planning of Eastern Surface coal Mining, Vol I: Executive Summary. EPA-600/7-78-180.Cincinnati, OH. 71p.
27. Ramsar. (2000). Wise use of wetlands. Handbook1.Gland, Switzerland: Ramsar convention Bureau.
28. Rwanda Environmental Management Authority (REMA). (2008). Economic analysis of Natural Resource Management in Rwanda. Rwanda environment Management Authority (REMA), Kigali.
29. Rwanda Environmental Management Authority (REMA). (2011). *Mining Sector Working Paper*. Appendix B.Done by Smith School of Enterprise and the Environment (SSEE)-University of Oxford in collaboration with Government of Rwanda.
30. Rwanda Mining Board (RMB). (2018a). *Mining Policy*. RMB: Kigali.
31. Rwanda Natural Resources Authority (RNRA). (2017). Upper Nyabarongo catchment rehabilitation plan, Kigali, Rwanda.
32. Sjoblom, A. (2003). Wetlands as means to reduce the environmental Impact of mine drainage waters.
33. Stoltz E, Greger M. (2002). Accumulation properties of As, Cd, Cu, Pb and Zn by four wetland plant species growing on submerged mine tailings. Environ Exp Bot 47(3):271-80.

34. Swede Survey (2010) project of Rwanda national land use and development master plan, report for production of the ortho photo in Rwanda.
35. Todd AK, Buttle JM, Taylor CH. (2006). Hydrologic dynamics and linkages in a wetland-dominated basin. Journal of Hydrology 319(1-4):15-35.
36. Tomovic, Gordana. (2006). "Kasovo on old maps from the XV to the XVIII century. Belgrade: Serbian Academy of sciences and Arts.
37. U.S. Environmental Protection Agency. (1976). Erosion and Sediment Control Surface Mining in Eastern US: Volumes 1 & 2. EPA-625/3-76-006Washington, DC.
38. Vanmaercke, M., Poesen, J., Broeckx, J., Nyssen, J. (2014a). Sediment yield in Africa. Earth-Sci. Rev. 136, 350–368.
39. Wesolek BE, Szkokan-Emilson EJ, Gunn JM. (2010). Assessment of littoral benthic invertebrate communities at the land-water interface in lakes recovering from severe acid- and metal-damage.Hum Ecol Risk Assess16(3):536-59
40. Zedler TB, Kercher S. (2005). Wetland resources: status, trends, ecosystem services, and restorability. Annual Review of environment and resources 30:39-74
41. Queensland Reconstruction Authority. (2011-2012). Planning for stronger, more resilient floodplains, state of Queensland, Queensland.