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Wetland Restoration and Farming Practices Prohibition towards Local Users' Livelihood Insights of Rugezi Wetland, Rwanda

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Abstract:- Wetlands are regarded as one of the most productive ecosystems, capable of providing invaluable ecological services; they are also an important component of our environment through improving the water quality in the area and make the local climate more temperate. Wetland restoration has received a lot of attention as a result of the loss or degradation of wetlands as the ecological restoration can help to improve the structure and function of degraded, damaged, or destroyed wetlands. Many restoration projects have been completed around the world using various restoration goals and methods. However, due to current quarrels on restoration definitions and concepts, assessing wetland restoration has become difficult. Therefore, to better manage and conserve wetland resources, we must first understand their distribution and extent, as well as monitor their dynamic changes as wetland maps and inventories can help with wetland conservation, restoration, and management. Geospatial techniques (GIS and remote sensing technologies) have proven to be useful for mapping and monitoring, restoring wetland resources. The objective of this study is to assess the impacts of wetland restoration and prohibition of agriculture practice on livelihood of local users and evaluation on status of Rugezi wetland restoration progress. Using the maximum likelihood pixel-based classification method, Land sat images was utilized to examine the historical and present state of the Rugezi wetland for the years 1982, 2002, and 2022. The result revealed that the restoration practice on Rugezi wetland was triggered by high rate of degradation due to agriculture and pottery activities and exacerbated by water reduction which led to a decrease in hydro-power production. Yet, the restoration practice indicates the positive changes on wetlands since the affected local community by restoration practice have gained some opportunities in wetland restoration. However, some wetland restoration measures have not achieved to its full capacity especially implementation of buffer distance (20m along wetland and 50m from the shores of Lakes). Therefore, a strong collaboration of local community, government authorities and private sector is essential to implement all restoration measures to its full capacity. The information obtained from the analysis of wetland restoration and its implications for the local community aids in the provision of optimal view for wetland restoration progress.

Keyword:- *Wetland restoration, Geospatial technology, Wetland degradation, Rugezi wetland.*

I. INTRODUCTION

Wetlands have already been identified as having the potential to provide long-term benefits to society and human well-being, with the practice of restoring wetland ecosystems enticing to recover some of these benefits in response to widespread degradation(Browne, Fraser, & Snowball, 2018). However, wetlands have been laboriously induced by humans, resulting in a loss of more than half of the wetlands globally, with significant repercussions and risks to fauna, human livelihood, and wealth distribution. Therefore, the restoration of this type of habitats is a must for the comfort of humanity (Rodrigo, 2021). This is mostly proven by the declaration of the United Nations in March 2019, whereby UN General Assembly declared the Decade of Ecosystem Restoration from 2021 to 2030. This will help to restore the ecosystems, which are being degraded at an unprecedented rate(Zhongming, Linong, Xiaona, Wangqiang, & Wei, 2019). and thus, integral wetland restoration must be contemplated within these preferences and efforts.

Rugezi wetland has been degraded over time due to agriculture activities, fire, and plant species overexploitation (Grundling, 2016). However, it was also affected by an environmental crisis caused by a decrement in water level and sedimentation (Sylvère, 2016). Agriculture practices has been highlighted among the most human induced degradation of wetland as they are at the forefront of the key indicators of human footprint and main driver of biodiversity decline (Gamfeldt et al., 2013; Nkonya et al., 2012).Such trends is particularly notable on African continent due to the pressure of rapid population growth and the need to fulfil socio-economic necessities of various users of land and spatial resources (Hooper et al., 2012). Apart from hillock farming, the splintering of household farms mostly through generation replacement, increased population pressure, and finite proxy because of employment prospects, marshes have been turned into farmed land. (Nahayo et al., 2016).The same source

indicates that such conversion is highly driven by the increase of the population with a need to sustain through making income generated activities. According to a recent study, Rwanda's population increased from 2.9 million in 1960 to 12 million in 2015, with a corresponding increase in population density from 102 to 471 people per square kilometre. This implies that with a rate of population growth of 2.7, the population is expected to reach 14million in 2025 (Rukundo et al., 2018).Based on that increase, there is a pressure on spatial resources in which overexploitation of available resources will result into environmental degradation. A key insight is taken on Rugezi wetland local users whereby between 1978 and 2000 the population who live in that region increased approximately to 75% while population density grew from 337 to 557 inhabitants per km^2(NISR,2012). Farming activities were the main economic activity of this population which eventually put some pressure on remaining part of the wetland; thus, increasing the level of spatial resources degradation (Nabahungu, 2012).

The high demand for agricultural land, settlement brought on by rapid population increase, and absence of appropriate rules for the sustainable use of Rugezi wetland resources have all contributed to its degradation (Nabahungu, 2012). Due to unsustainable agriculture, there is also a natural forest cover being cleared and replaced with ineffective agricultural which resulted to a reduction of biodiversity, this has also resulted to a decrease of accumulated organic matter in the soil and reduce carbon uptake, nutrient recycling, infiltration and rain water retention(Kazoora & Hagwirineza, 2011). Due to precipitation fluctuations and suboptimal agricultural management in the watershed, water levels in the Rwanda's main northern lakes have dramatically cascaded during the previous few years (Browne, 2018). The outcome is a low water table, a decreased hydro-potential, and decreased agricultural output in the area. Utility rates increased as a result of countrywide electricity shortages between the years 2004 and 2006 (Hategekimana, 2007). The basins around Rugezi Wetland are still inhabited by rural populations relying on themselves to satisfy their needs in terms of food, water, and other livelihood. Conflicting demands place a burden on the local watershed, and nobody is making an effort to save it or insensitive to conserve it (Safari, 2010). Both challenges will definitely become more serious as a result of emerging climate change impacts in this region, including more frequent prolonged and severe droughts (Sylvère, 2016). As a result, the Rugezi watershed is burdened by three issues: the local deterioration of the watershed, the national energy crisis, and the issue of livelihood dependency as all those burdens are mainly stretched from water resources shortage and loss of ecosystem(Sorensen, 2016).

Rugezi wetland is claimed to be a niche of biodiversity and ecosystem based on its nature (Nsengimana, 2019). As it is highlighted by elders among local users of the wetland, Rugezi was once a non-intact wetland whereby the reclamation policy was developed in 1960 (Sylvère, 2016) that highlight a legislative structure created to address the issue of land shortage by properly allocating new wetlands, resulting from conversion of wetland into agriculture use, from that period, the local users to get livelihood along Rugezi wetland rely on subsistence agriculture as source of income and practice of pottery activity through using a wove generated in wetland(Rukundo et al., 2018).The wetland was reclaimed under two project initiated by Japan International Cooperation Agency (JICA) in1968 and later in 1996, by International Fund for Agriculture Development, IFAD (Kipwola,2020).This was done through construction of lateral channel to drain excess water in order to gain agricultural land. According to National Institute of Statistics of Rwanda, NISR,(2015),the majority of population relying on subsistence agriculture as their main source of income along Rugezi wetland, specifically in Burera and Gicumbi district, increased at 75% while population density also grew from 337 to 557 inhabitants per km^2between 1998 and 2000(Nabahungu, 2012).

The wetland continued to be deteriorated in 2002,mostly dominated by agriculture practices, population pressure and degradation of uplands which was considered as a key reason for cultivating in Rugezi wetland (Grundling,2016).In 2005,the government of Rwanda has established the National Environmental Policy with its implementing governmental institution, Rwanda Environment Management Authority (REMA).This institution was created in order to regulate and address the issues of growing natural resources (Gakuba,2011). Conservation efforts remained, however, limited by gaps in the new environmental policy's implementation and monitoring (Hategekimana, 2007). For the utility, increasing hydro-potential through building additional stations and the relocation of marsh farmers was the only option to restore the energy grid (Kipwola, 2020). Neverthless, in the Rugezi wetland, the Rwandan government's inability to address the country's high population density, lack of available land, and declining natural resource like topsoil and timber left rural residents with no choice but encroachment on the fertile marsh soils.

Both parties require and desire to use the Rugezi wetland as a supply of water. However, Rwanda faces the possibility of losing its useful hydropower and/or continuing resource conflicts in the north region. Indeed, in 2005, the government of Rwanda under REMA adopted some measures to restrict all activities that operate within wetlands and later in 2006 Rugezi wetland gazetted as a Ramsar site (Nsengimana, Becker, Ruhagazi, & Niyomwungeri, 2019). The initiated wetland restoration approach tends to restore the degraded ecosystem and stabilize water resources to the extent that it generates hydro-electric power. Rugezi wetland was restored mainly to increase hydro-electric power potential that was affected by water reduction; flooding and mudslides had also frequent trends affecting wetland. The initiation of restoration practices has contributed to reduction of floods and mudslides which was also frequent trend that affect wetland. The initiation of restoration practice has contributed to reduction of flood and mudslides and prevention of long-term downstream dysfunction and overcome large scale climate impacts and change of weather pattern(Kipwola, 2020).

The restoration practices are initiated mainly for ecosystem restoration. Ecosystem services are the "benefits given by ecosystems restoration, including providing, regulating, cultural, and sustaining functions," according to the Millennium Ecosystem Assessment 2005. The source indicates that foods, fabrics, and fuels are all included in provisioning services. In addition, the prevention of drought and floods, control of pathogens, taming of extremes weather and their effects, and purification of the air and water are all examples of regulating services. Furthermore, cultural services are elements of aesthetic, beauty and legacy. Finally, cycling, transporting nutrients, and maintaining biodiversity are indicated as examples of supporting services(Gatwaza & Wang, 2021).

It was not until 2005 that the government of Rwanda begun to put the idea of supporting sustainable development through the creation of clear links between development and sustainable wetland conservation into practice (Kubwimana, 2019). This was in response to the call for study on the effects of wetland restoration. In this regard, the government of Rwanda has promulgated the Organic Law on Environment Management and Conservation by establishing the organization tasked with overseeing, assessing, and assuring the inclusion of environmental considerations in all local and national programs (Kubwimana, 2019). The significance of the Rugezi Wetland has continued to be emphasized in policy development. The release of the Sustainable Development Goals, in particular SDG 15 on "Life of Land," is a step in this direction that increase biodiversity preservation, restoration, and promotion, as well as sustainable forest management, and stop biodiversity loss (SDG, 2019). Due to its features and services, the Rugezi wetland has gained attention from policymakers. This demonstrates that the aforementioned international, national, and local regulations all maintain the need to restore this wetland. In order to inform present and future decisions on the restoration and sustainable use of the Rugezi wetland, it is necessary to offer decision-making on the historical evolution of the functions and services of the wetland. This paper discusses the impacts of wetland restoration and prohibition of agriculture by making reference on livelihood of local users. It refers commonly to the past livelihood of local users and their current livelihood after restoration practice basically on consideration of three key anchors which is impacts on environmental sustainability, social inclusion and economic benefits.

The Rwandan government adopted a restoration measure at national level, intended to restore degraded and ensures environmental protection and sustainably managed environmental management under national environmental policy (Hategekimana, 2007).The policy's recommendations for wetland management include encouraging the repair of wetland ecosystems that are deteriorating, reintroducing endangered species, and putting protection measures in place for slopes to stop the deterioration of wetlands (van Oosten, 2018). The goal of the nation's biodiversity policy is to eradicate, control, and prevent threats to biodiversity. It also emphasizes the importance of wetlands for sustainable development and environmental soundness outside of all protected areas (van Oosten, 2018). In the meanwhile, maintaining the diversity of populations, habitats, species, wetlands, and landscapes communities in the nation remains a strategic goal to restore ecosystems by employing biological resources sustainably while limiting negative effects on biological variety (Zhongming, 2019). However, increasing human capacity for wetlands conservation, managing their usage, and addressing their threats encourage biodiversity conservation and sustainable usage. This is made possible through creating circumstances and incentives that are among the vision of the government of Rwanda by promoting ecosystem restoration(Kahindo, Bates, & Bowie, 2017).

Moreover, wetlands are considered to be among useful and productive ecosystems on the earth; yet they have been continuously deteriorated, until nowadays wetlands continue to be at endangered point of deterioration and complete destruction (Clarkson, Ausseil, & Gerbeaux, 2013). Historically, wetland areas were highly occupied by other uses, specifically agriculture in which different restoration practices have resulted into its decline, whereas the trends highlighting restoring wetlands to function can reverse the tendencies mentioned above (Zhao et al., 2016). Additionally, crop yields on former wetlands are frequently marginal (Nabahungu, 2012). This suggests that farmers should free and offer these lands for rehabilitation. It makes logical sense for taxpayers to pay the farmers for restoration on their land given that such a practice might be advantageous to society as a whole (Yepsen et al., 2014).This is particularly notable on Rugezi wetland which was mainly used by local population for food production during the period between 1980-2000. Such land use has enormously contributed to wetland degradation until 2004 (Hategekimana, 2007). Generally, different factors that contribute to wetland degradation include the population growth, limited governance capacity and unclear tenure regimes. Also, there is a reliance on subsistence agriculture extended to the steep slopes which, combined with deforestation, increase surface runoff, soil erosion and siltation of the wetlands(Hategekimana & Twarabamenye, 2007).

Through the 2004 National Land Policy, the land reform undertaken in Rwanda with specific attention to good management of the environmental sensitive areas includes various mechanism of wetland restoration. Some of relative interventions include plantation of forest on side of wetland to reduce tremendous erosion from hill side, and removal of all activities that operate within wetland in order to restore it. In this fashion, Rugezi wetland was gazetted in 2006 as a Ramsar site by the Government of Rwanda (Nile Basin Initiatives, 2019). The restoration of Rugezi wetland affected the livelihood of the local community that lost access to a subsistence agriculture practices and related benefits. Despite this, the restoration practice that was initiated appears to start providing some benefits, eventually new opportunities to local population livelihood with less than they once benefited from crop production. Unless those primitive measure for its restoration result into decline of crop production. Therefore, an analysis and projection on Land Use changes can provide a tool and access, and quantify ecosystem changes and their effects on the

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environment at different temporal and spatial scales. (Haregeweyn, Fikadu, Tsunekawa, Tsubo, & Meshesha, 2012).

However, there have been some studies related to the impacts of wetland restoration specifically on Rugezi wetland. For instance, Hategekimana & Twarabamenye(2016) have studied social network analysis to understand actors participation and influence on sustainable management of Rugezi wetland. The same authors also analysed the importance of stakeholder's participation in wetland management as it reflects the importance of restoration of wetland which was once degraded by agriculture practices. In the same vein,Grundling, Grootjans, & Linstrom(2016) studied the importance of wetland restoration on environment and local community through referring on past and current use of wetland. In sum, these studies have demonstrated the impacts of wetland restoration on environment, social and economic benefits for local wetland users particularly on Rugezi wetland.

In view of that need, the paper aims to assess the impacts of wetland restoration and prohibition of agriculture practices for the livelihood of the local users on Rugezi restored wetland. The study seeks to assess the status of Rugezi wetland before restoration practice. Specifically, the study will analyse the impacts of wetland restoration and prohibition of agriculture practice on the livelihood of the local users.

Therefore, the related impacts of wetland restoration and prohibition of agriculture practice on Rugezi wetland will help local authorities at sector and district levels to have a reflection on outcomes of restoration measures against the livelihood of local wetland users. The contribution of this is to show a clear view on livelihood of local users along Rugezi wetland after restoration practice as it can simply reflect the importance of wetland restoration so that the approach can be applied in restoration practice for another reclaimed wetland. There will be usefulness of identified impacts for scholars, decision makers, non-governmental organizations, and any other institution whose interest is in wetland restoration practice.

II. MATERIALS AND METHODS

A. Study area and sampling

Rugezi wetland is taken as the only Ramsar site in Rwanda, located in Northern Province, Burera and Gicumbi District. It is surrounded by six sectors, namely Butaro, Ruhunde, Kivuye, Gatebe, Rwerere, and Cyeru, within the Buberuka highlands. Its boundary stretched from southern latitude $1^0$21'30'' and $1^0$36'11'' and eastern longitudes $29^0$49'59'' and $29^0$59'50''. According to a report on 4th Population and Housing Census of Rwanda in 2012, carried out by the National Institute of Statistics of Rwanda(NISR), the population density was estimated between 477-522inhabitants/km^2 with farmland ranged from 0.15 to 0.2 ha per household(NISR, 2015). Most of the residents around the wetland are farmers who domesticate animals at home and feed them on the planted grass.

The Northern Province is comprised of different wetlands which drain on 2 valleys namely Rugezi and Kamiranzovu whose sizes are respectively 26km length and 3km width, all those valleys are made of streams which meet at 2050m altitude as they flow into Lake Burera in 200m downstream. The reason behind crops production in Rugezi is linked to a high population pressure and continuous deterioration of uplands. Apart from agricultural use, Rugezi wetland experience two different vulnerable criterions which is considered to be hydrological criterion and biodiversity, It is also surrounded by two hydroelectric power plants, namely Ntaruka (between twin lake of Burera and Ruhondo) and Mukungwa station in the downstream of Lake Ruhondo (Benineza, Rwabudandi, & Nyiransabimana, 2019).

The same authors revealed that the districts experience two main types of climates, the tropical rainforest and tropical savannah climates with the latitude ranged from 2060m up to 2312 m above the sea level. The relief is mainly consisted of steep slope hills linked either by steep sided valleys or by flooded marshes. The region experiences annual rainfall ranging between1400 mm to 1800 mm with annual minimum temperature averaging between 9℃ and 25℃. Rugezi wetland is also taken as an Important Bird Area (IBA) in which it operates under recognition of the Bird Life International (BLI) in 2001. In addition, it is reserved to be a niche of 43 species of birds within and in the surrounding areas of the wetland; in which it occupies 8,500 hectares(Hategekimana & Twarabamenya, 2007).

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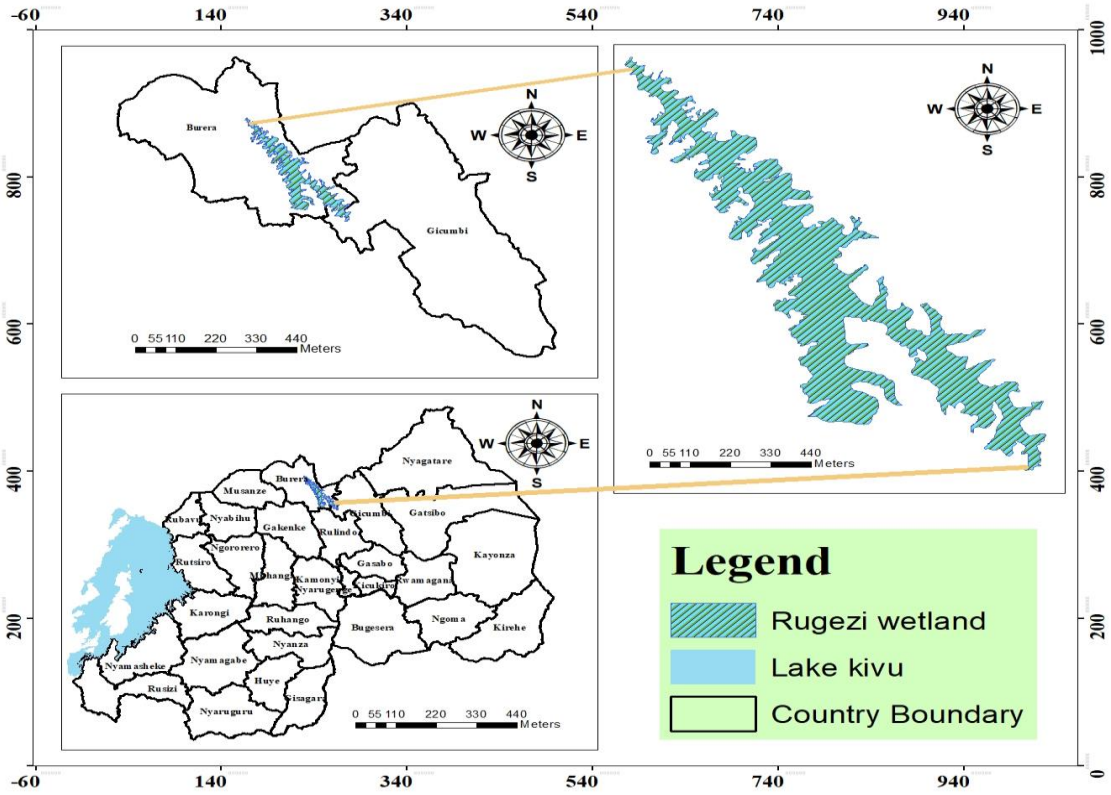

Fig. 1: Administrative boundary of Rwanda and location of Rugezi wetland

For sampling techniques, both random and purposive sampling methods were applied in selecting participants to the interview, specifically addressed to the local community along Rugezi wetland. The universe population consists of all people living in eight sectors around Rugezi wetland in Burera (Butaro, Ruhunde, Kivuye, Gatebe, Rwerere, Rusarabuye and Cyeru) and Gicumbi (Nyankenke and Miyove) districts. Also, the involvement of Burera youth community among conservationists is considered. The considered population in this research was based on the results of the 4th Population and Housing Census in Rwanda of 2012 by NISR.

SECTOR	POPULATION
Rusarabuye	18,396
Butaro	31,520
Kivuye	15,448
Rwerere	18,310
Ruhunde	16,975
Gatebe	16,556
Nyankenke	21,560
Miyove	16,299
TOTAL	**155,064**

Table1: Population distribution per sector in both Burera and Gicumbi District

Source: NISR, 2012

The number of local communities who participated in this study was selected using the following sampling formula, which is applied in the finite (Krishnaswamy, Sivakumar, & Mathirajan, 2006) as follows:

It is computed as $\mathbf{n= N/ (1+Ne^2)}$ (1)

Whereas:

N = population size

e = the tolerable error (10% in this study)

So, **n** is computed as $\mathbf{155,064/ (1+155,064*0.1^2)}$ = **99.9~**

n=100

As the study area was extended to eight different sectors of two different districts, the calculated sample size was distributed proportionally and12 respondents were interviewed in each sector. The four people remaining were purposively added to Burera district, which has a big part of Rugezi wetland. In addition, some active member of Burera youth community were included among respondents as a focus group discussion. It was realized that one person out of four could participate in the interview since the response related to the past and current status of wetland after restoration seems to be the same as long as the local natives of the sector who live near wetland is more privileged.

B. Data collection

a) Secondary data

For secondary data, a well-consolidated literature review on wetland management around the world and in Rwanda, particularly on restoration practice, was carried out. The study relied on existing spatial data-sets from different sources. The study used available Land sat images delivered from online satellite image repository known as the United States Geological Survey (USGS) repository for three time periods by considering time range of 20years (1982, 2002, and 2022). All Landsat images were recorded under

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"path" 173, "row" 61. The year of 1982,2002,2022 were preferred because the time range of 20years can greatly help to detect changes that have been taken place (Rebelo, Scheunders, Esler, & Meire, 2017). Additionally, the year of 1982 was preferred because through that period, the local community considered wetland as a place reserved for agriculture without considering ecosystem management, this is particularly notable on Rugezi wetland as the livelihood of local users in past periods depended on subsistence agriculture and pottery activity as source of income. For the year 2002, the degradation of the Rugezi wetland was already identifiable. Fortunately, in 2004, the government of Rwanda has restricted all activities that were degrading Rugezi wetland whereby 2006, Rugezi wetland was gazetted as Ramsar site. Due to different ongoing restoration project, the year of 2022 was preferred for classification analysis due to the fact that the wetland has partially restored to the extent that the agricultural practice is removed and other uses. Therefore, all those years highlight the past and current status of Rugezi wetland specifically on prohibition of agriculture practice and wetland restoration. Technically, the selection of Land sat image that is used is greatly based on availability of medium-resolution image and need of avoiding haze and high cloud cover content.

b) Primary data

For primary data acquisition, field observation and face-to-face structured interviews were conducted to ensure that the analysis reflected various converging evidences. The interview was carried out in April 2022 as well as the field observation. The main aim of the structured interview was to acquire clear views on livelihood of local community after prohibition of agriculture practices on Rugezi wetland and initiation of restoration practices.

Dataset	Time recorded	Resolution	Source	Particularity	Purpose of use
Multi-spectral scanner (1-5)1982	06-November-1982	30m	USGS	Not –pan sharpenable	To create LULC map
Landsat7ETM+2002	12-October-2002	30m	USGS	Not-pan sharpenable	To create LULC map
Landsat8OLI/TIRS2022	10-March-2022	30m	USGS	Not –Pan sharpenable	To create LULC map
Wetland shape file of Rwanda	2018	1.200.000 scale	CGIS	Well visualized	Delineating Rugezi wetland boundary

Table 2: Spatial datasets description

C. Data processing and analysis

a) Data pre-processing

For pre-processing activity, the downloaded images were with less than 15% cloud cover content and were mosaicked and geo-referenced using WGS 1984 UTM coordinate system Zone 30N. The pre-processing exercise was followed by a subset of different satellite images, based on specific objectives in which three Landsat images of 1982, 2002, and 2022 were extracted to extent Rugezi wetland using its boundary data. The figure 2 above shows the geo-processing steps used to generate LULC maps. It highlights generally the inputs data and the expected result after classifying the satellite images. The input data used were different Landsat imagery found on United States Geological Survey digital repository (USGS). Furthermore, the pre-processing activities of haze reduction, cloud cover content reduction and band combination were also performed to generate a single image of combined bands that helped to extract the area of interest. Finally came supervised classification using maximum likelihood classifier techniques and accuracy assessment to generate and quantify LULC change maps.

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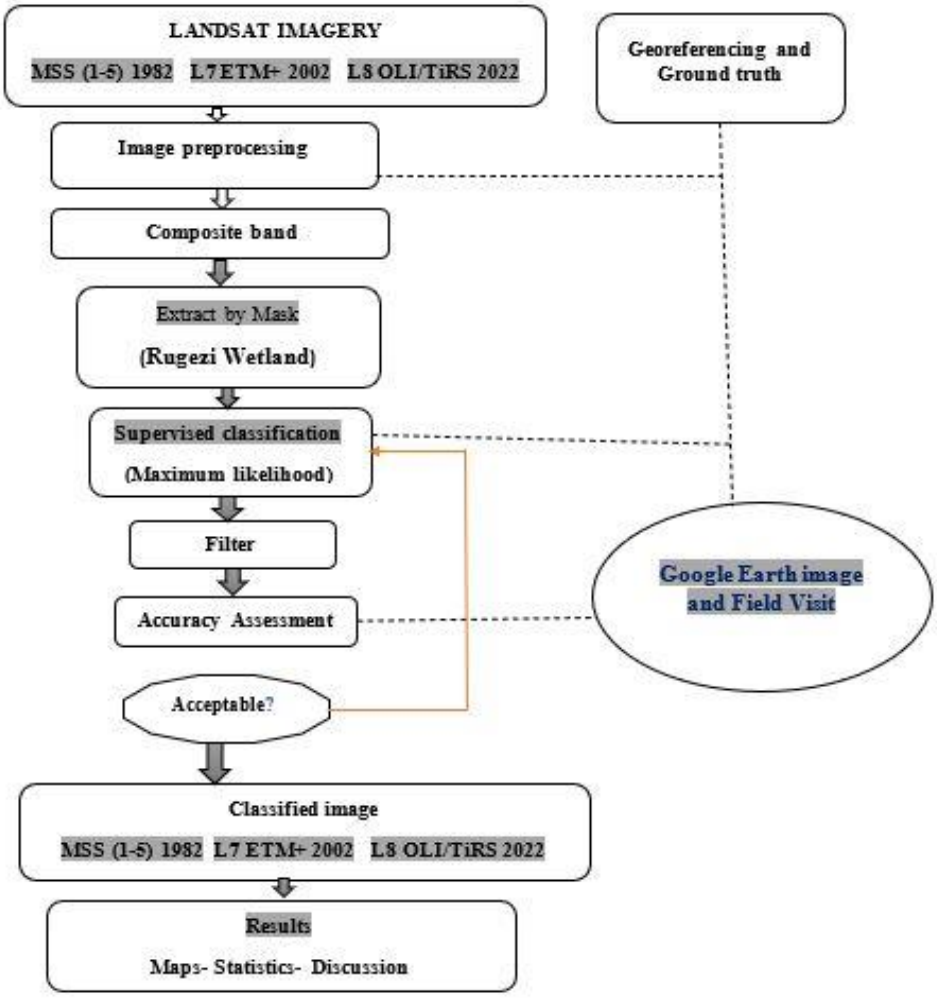

Fig. 2: Analytical framework for remote sensed data

b) Data analysis

Acquired remotely sensed data were performed through Landsat imagery. As described above, image classification was processed to facilitate data analysis and extract needed information. This image classification was made on the basis of a supervised classification through maximum likelihood classifier approach, and it is highlighted to be taken as an essential tool for extracting qualitative information and visualize them from remotely sensed data(Mugabowindekwe & Rwanyiziri, 2020). The image classification analysis led to identification of both spatial and temporal changes that took place on Rugezi wetland. An analysis process and interpretation of collected data (both spatial and non-spatial), GIS and remote sensing methods (ArcGIS10.5 and Erdas imagine 2014) were used. Due to different capability of functioning, Erdas imagine 2014 was used for image pre-processing specifically haze reduction and band combination. ArcGIS helped in image analysis through supervised classification technique and delineation of final land use land cover map. The image was classified under 5 classes' namely agricultural land, forest, wetland, and water body and built-up. Based on different Landsat images, band combination was performed. For multi-spectral scanner (1-5) of 1982, the preferred band combination was natural colour (3, 2, 1); Landsat7 ETM+ of 2002 the preferred band combination was colour infrared (4, 3, 2), as for Landsat8 OLI/TIRS of 2022 the preferred band combination was colour infrared combination of (5, 4, 3). For each class, the minimum taken points as training samples were 80points. Microsoft excel was used to compile and analyse statistical data generated as interview responses and analysis on result delivered from final classified images through generating a well visualized graphical and tabular illustrations. Excel has a complementarity with SPSS software capability. However, the SPSS software was considered to be the best tool for performing statistical analysis, modifying them and leading tool in performing both descriptive and inferential statistics.

Ground truth data was gathered at the 60-land cover reference point for validation and overlaid on high-resolution satellite images of Google Earth in order to assess and validate the classification accuracy. For training site construction, spectral and spatial characteristics as well as auxiliary data like Google Earth images were used for increased accuracy.

ISSN No:-2456-2165

The following formula were used to calculate the accuracy evaluation, Kappa coefficient, and wetland occupation change analysis after creating final maps using the coverage area.

$$\text{Overallaccuracy} = \frac{\text{total number of correctly classified pixel(Diagonals)}}{\text{total number of Reference pixels}} \times 100$$

(2)

$$\text{Kappacoffiecient} = \frac{Ts \times TCs - \sum(\text{Column total} \times \text{Row total})}{Ts^2 - \sum(\text{column total} - \text{Row total})} \quad (3)$$

$$\text{Useraccuracy} = \frac{\text{Number of correctly classified pixels in each category}}{\text{Total number of reference pixels in that category (the Row total)}} \times 100$$

(4)

$$\text{Produceraccuracy} = \frac{\text{Number of corrected classified pixels in each category}}{\text{Total number of reference pixels in that category (the column total)}} \times 100$$

(5)

Where T(s) is total sample and T (cs) is total corrected sample

Total LULC Gain/loss= Area of the final year-Area of the initial year (6)

Percentage of LULC Gain/loss= Area of the final year-Area of the initial year/ Total area of occupancy (7)

The following table presents the accuracy assessment of the classified images where both the Producers and Users' Accuracy were calculated. Apart from calculation below, another calculation of Kappa coefficient and an overall accuracy of classified images were also done and established. It is in this regard that after post-classification filtering, the following overall accuracies and Kappa coefficients were obtained.

	User accuracy (%)					**Producer accuracy (%)**				
Year	**Wetland**	**Agricultural land**	**Water body**	**Forest**	**Built-up**	**Wetland**	**Agricultural land**	**Water body**	**Forest**	**Built-up**
1982	95	100	100	94.5	97.9	96	92	100	94	100
2002	94.6	90	83.5	70.8	95.5	92	80	92	80	96
2022	96.9	100	95.5	96.7	93	95	95.5	100	96	92
Average	**95.50**	**96.67**	**93.00**	**87.33**	**95.47**	**94.33**	**89.17**	**97.33**	**90.00**	**96.00**

Table 3: Accuracy assessment of classified images

Year	**1982**	**2002**	**2022**
Overall accuracy (%)	96.95	87.44	96.06
Kappa coefficient	0.9495	0.8524	0.9405

Table 4: Overall accuracy and Kappa coefficient of classified image

III. RESULTS AND DISCUSSIONS

A. Status of Rugezi wetland before restoration and its spatial pattern after restoration

Rugezi wetland is an important and a unique functionality that has large local,reginal and global impacts. However, since the water from the region drains in the White Nile and the Congo Rivers, there is a severe deterioration to this system. This region's hydroelectricity is a significant source of energy for Rwanda. Before restoration, the wetland was once occupied by agriculture practices as dominant of the use of wetland. An analysis on spatial pattern of wetland before restoration revealed that there is a part of wetland drained due to biophysical disruption has continued to reduce carbon uptake and nutrient recycling and poor retention of infiltrated rain water.

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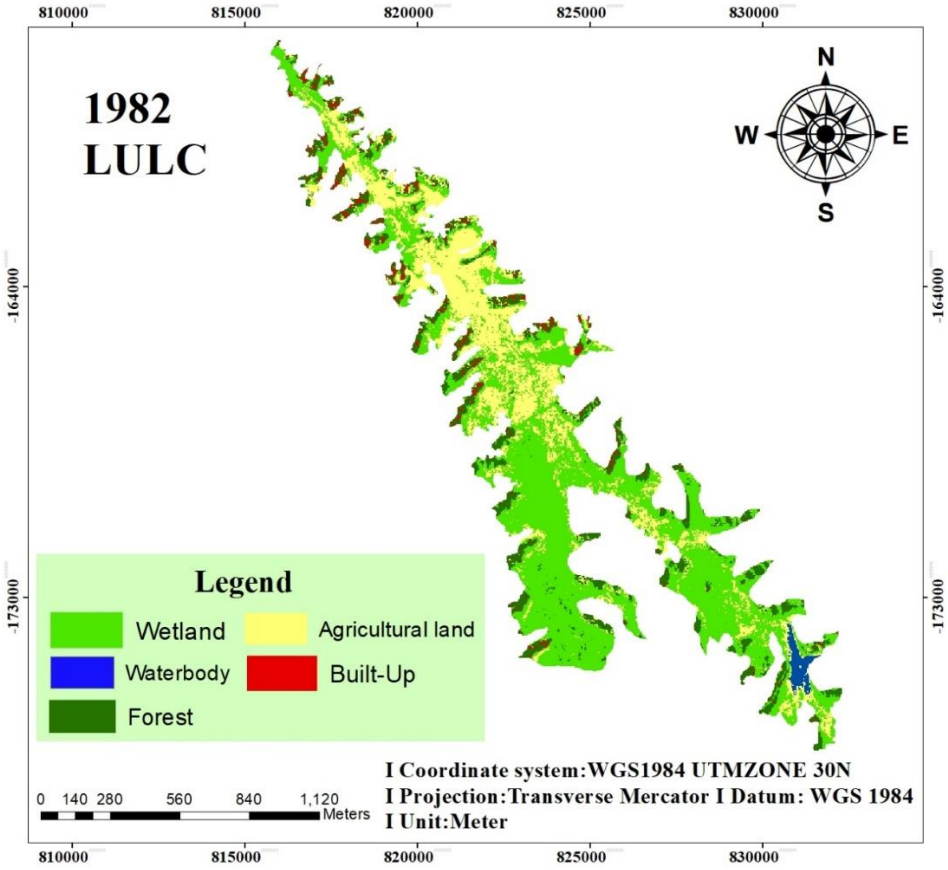

Fig. 3: Rugezi wetland status before restoration

The situation continues in later 2002 with a serious deterioration of this important system. Farmlands have been created on the previously forested hillsides. An overall decrease in ecosystem functions has resulted from this decline of natural forest, especially biodiersity loss as the biomass and accumulated organic matter have caused moisture,evapoation, transpiration and water table drop rate to be altered and reduction of nutrient recycling.This degradation of wetland has resulted to long-term and immediate implications to local people and downstream in the river catchment.

The direct consequences are considered to be continuously soil erosion with reduced fertility and high sediment level of muddying with clogging of infrastructure basically hydro electric power plant. Economically, for agriculture productivity the soil continues to degrade, which causes poverty and food insecurity to rise yearly. Without action, the state of deterioration will only get worse for long which may result to decreasing of fertility and productivity with the increase of poverty to local wetland users and lowered hydro electric potential. Environmentally, the continuos degradation without restoration tends to cause mudslides,flooding and long-term downstream dysfunction with also large scale climate impacts and the change of weather pattern.

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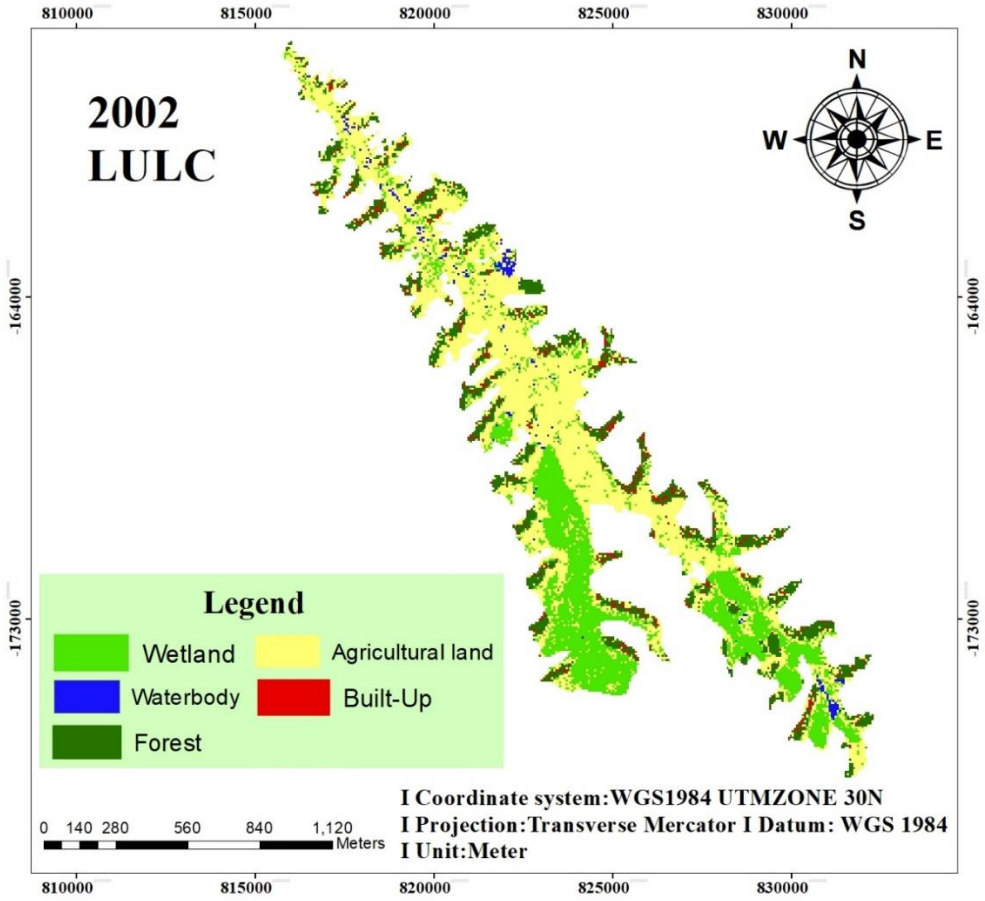

Fig. 4: Continuous degradation of Rugezi wetland in 2002

After such long term of Rugezi wetland degradation, the approach of restoration was initiated by the government of Rwanda with the purpose to re-gain degraded ecosystem and stabilise water table drop in order to increase the potential of power plant to produce electricity. Indeed, the problem in Rugezi seems to be caused by unsustainable agriculture methods, there were existing favorable conditions that suggested the potential rehabilitation of Rugezi wetland. First there was solar radiation and and sufficient water to generate a great deal of biomass and this scientifically and technicaly showed that it is possible to restore most of degraded of ecosystem and even hydrological functionality.

The restoration practice has achieved some of it main aim specifically the reduction of flooding and mudslides and prevention of long-term downstream prevention and maintainance of hydropower potential through ecosystem restoration. The restoration also achieved its purpose of planting forest on side of wetland and terraces on it upper highlands of Buberuka to protect the wetland from soil erosion (Lamek et al., 2016). Moreover, the capacity of hydro-electric power generated has also increased since Ntaruka hydro power plant has experienced a reduction in electricity geneation. This was due to significant drop in the depth of lake Burera which act as reservoir of Ntaruka stations and this decline was directly caused by poor management of Rugezi wetland by different induced human activities which reduce prior the precipitation throught year(Sorensen, 2016). As a solution, the government of Rwanda sought to restore Rugezi wetland through halting ongoing drainage activity in wetland and banning agriculture practices .However, banning both agricultural and pastoral activities has affected the productivity of the local livelihood. In recognizing this, government implemented a suite of watershed and agriculture management measures.This was done in order to promote rural livelihood sustainability all under integrated management of critical ecosystem project under REMA(Grundling et al., 2016). These achieved measures include the establishment of a belt of bamboo and pennisetem grass around the Rugezi wetland so that the local community can get the pasture of their cattle without degrading wetland,there is also a construction of structure intended to control erosion with also a plantation of trees on hillside and distribution of cookingstoves. Economically, the government has initiated the promotion of income generating activity to local community like beekeeping. All those practice has resulted to operation of Ntaruka and Mukungwa hydro power plant to its full capacity(Hove, Parry, & Lujara, 2011).

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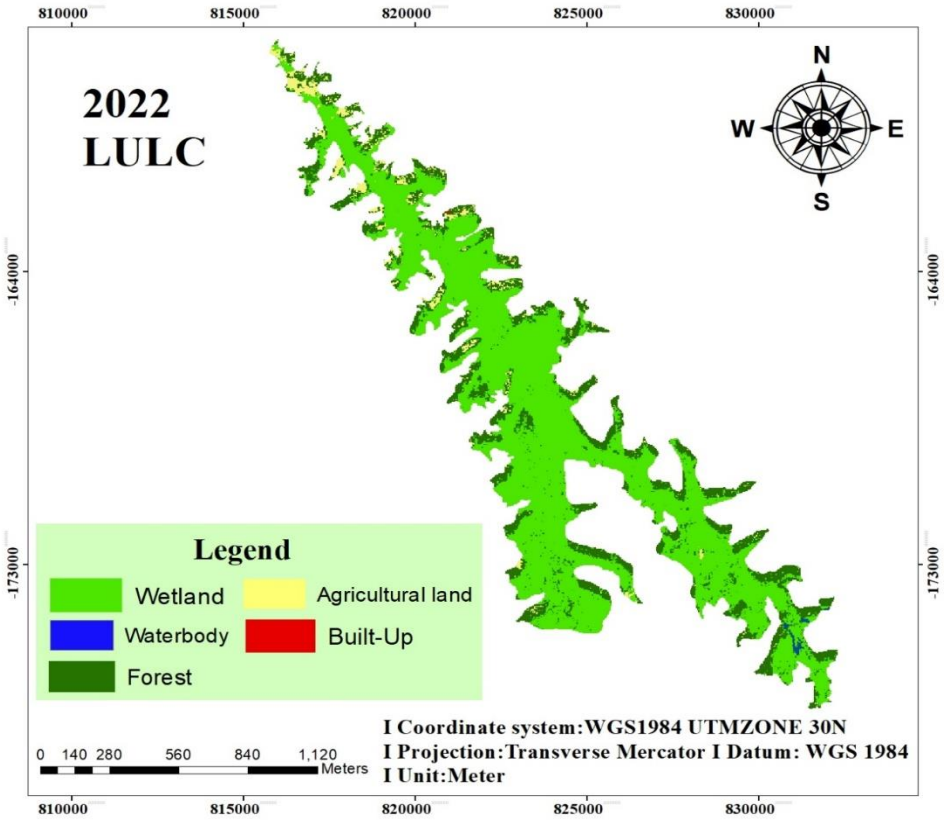

Fig. 5: The current status of Rugezi wetland after initiation of restoration

Classes	Area in sq.km/ 1982	Change in %	Area in sq.km/2022	Change in %	Change in sq.km between (1982-2022)	Change in %	Status
Wetland	36.87	55.70%	47	71.01%	11	32.87%	Increase
Agricultural land	17.71	26.76%	3.19	4.82%	-14.52	43.3%	Decrease
Water body	2.72	4.11%	1.85	2.79%	-0.87	2.59%	Decrease
Forest	7.62	11.51%	13.81	20.86%	6.19	18.47%	Increase
Built-Up	1.27	1.92%	0.34	0.52%	-0.93	2.77%	Decrease
TOTAL	66.19	100	66.19	100	33.51	100	

Table 4: Spatial pattern of changes on Rugezi wetland from1982to 2022

Wetland restoration measures along Rugezi wetland has resulted to such dramatic change of use,whereby the size of wetland class has been increased 32.87% in 40 years. Due to different measures and approach that is used for wetland restoration, the land occupied by forest has also increased 18.47% in 40years. The wetland restoration approach has resulted to proper regain of the part of wetland that was once intacted by agriculture practice,this has also result to development of wetland ecotourism activity such as birdwatching, research based activity as restoration practice have opened the corridor for different biodiversity that have migrated specifically bird. Wetland based eco-tourism activity was among the purpose of restoring Rugezi wetland as it is included among Ramsar convection aggreement.

Based on responses generated through structured interview addressed to local natives of Rugezi wetland and agricultural officer per sector level specifically on those eight sectors that share boundary with Rugezi wetland, Thereis such re-gain of part of wetland that's was once intacted by agriculture activities. The local natives along Rugezi wetland insisted on its use during the period between 1982-2002. They used this wetland for cultivation of maize at great extent but since the wetland was gazetted and also took among Ramsar important sites in 2006, the restoration practices have totally changed the used, from cultivated area to protected one. The decision has affected the local users livelihood ,and this has also been taken as truth because an analysis on the LULC 2022 has shown that there is such decline of 14.52km^2 of land used for agricultural in 40years, with increase of 11km^2 as land occupied by wetland due to restortion practice. According to REMA, the policy on use and management of wetland does not allow such other activities being operated on wetland in order to promote its rapid restoration. Since Rugezi wetland is a home of different biodiversity species, its restoration and protection is a must to preserve this niche.In fact, new measures taken to overcome the degradation of restored part of wetland by local users, include creation of cooperatives where former farmers who used to cultivate on Rugezi wetland meet together and form consolodated cooperatives. In terms of intensive agriculture, they are in partnership with Rwanda Agriculture Board(RAB) which help them to get selected seeds for maize and beans, and also organic fertilizers.

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Other laws were also promoted, endorsed, and put into effect in order to preserve the wetland. The Prime Minister issued Order N°006/03 of 30 January 2017 outlining the features and borders of marshes and lands as well as the procedures for their use, development, and management within this legal framework. This has greatly showed the importance of restoration practice along Rugezi wetland in which the practice is initiated to another reclaimed wetland in Rwanda.

B. The impacts of wetland restoration and prohibition of agriculture practice on the livelihood of the local users

The impacts of wetland restoration and prohibition of agriculture practice on livelihood of local users are mainly divided into positive and negative as they are all reflect their outcome under environmental sustainability,social inclusion and economic benefits.

a) Environmental sustainability

Environmentally, wetland restoration has resulted to proper control of flooding which was once considered among key driver of wetland degradation due to loss of water regulation capacity. This is initiated through making terraces and planting forest on side of forest to enhance the sustainability of wetland. For sustainable conservation of wetland there is a practice of planting forest on side of wetland at buffer zone of 20m. According to the information gathered from focus group discussion, they highlighted the collaboration of REMA and RAB in protecting the buffer zone of Rugezi wetland. This is done through forest plantation and the practice is also initiated through local community participation in both plantation and protection purpose.

For sustainable wetland conservation, Burera youth community think on measures that can be initiated to reduce the rate of wetland degradation, hence promote sustainable conservation. It is in this regard that Burera youth community has initiated a non-governmental organisation known as "***Be wise initiatives***" intending to protect trees specifically in Rugezi wetland. Their practice is mainly based on data collection on effect of wetland to local community as all this practice result to good collaboration with IPRC Kitabi (former Kitabi College of Conservation and Environmental Management) and REMA. This joint ventures is mainly based on reducing the degradation rate of wetland by local community through searching for pasture, establishment of different reed nurseries along Rugezi wetland by IPRC Kitabi, where it also gives to local community a young reed seed to be planted on their plot of land. This practice has significantly been considered as a measure to reduce the degradation of the wetland; hence, promote sustainable conservation since local community can also cultivate reed as pasture of their cattle without deteriorating wetland grasses.

b) Social inclusion

As Rugezi wetland is restored to its full capacity, the livelihood of local users has been impacted by prohibition of agriculture practices and other activities. According to the information provided by Burera youth community in charge of Rugezi wetland protection and conservation, they highlighted that local community usually intervene in practice of collecting grasses in wetland for their cattle. Addressing this issue, Burera youth community in collaboration with IPRC Kitabi, developed reed nurseries along wetland are considered as solution while forbidding the destruction of wetland in search grass for their cattle. This measure is not only favourable to sustainable wetland conservation but also a solution to social group of people that were affected by wetland restoration measures since they depend on it before restoration.

Social group that uses wetland resources for pottery activity known as "Batwa" have been greatly impacted by restoration practices since extraction of clay in wetland is also highlighted to be in main wetland degradation practice. Their livelihood after restoration is mainly based on income that they generate monthly as wetland rangers. This is greatly proven by responses gathered from interview with local community where they insist by saying that Batwa people is also among wetland rangers so their livelihood depend on income generated as wetland rangers.

c) Economic benefits

Economically, the livelihood of local users along Rugezi wetland was mainly depend on subsistence agriculture as source of income and other social activities such as pottery and weaving. Based on responses from interview addressed to local community along Rugezi wetland, 80% of them highlight a decrease of income after prohibition of agriculture and other activity in wetland. The restoration practice has prohibited all those activity that degrade wetland while benefited by local users, but restoration practice has also provide some benefit to local community as way of generating some income .some local users were selected as wetland rangers in which they get their monthly salary in collaboration with Rwanda development board, the main activity of hiring those local community who was once degrade wetland through agriculture, grazing, pottery activity is to restrict the group of wetland degraders known as "Abarembetsi" also they report all those who use wetland inefficiently in activity like bird poaching, bush fire, since all those who use inefficiently wetland are their neighbours when they report him/her it is difficult to repeat the same mistake of destruction due to heavy penalty and they push on them. Therefore, such involvement of local community among wetland rangers is considered as measures of promoting sustainable conservation of wetland from its destruction.

ISSN No:-2456-2165

After restoration the financial income generation of livelihood is also based on cooperatives that the form mainly reserved for art and craft. As wetland is a source of raw materials that is used for craft specifically papyrus, it can be extracted inefficiently hence result to poor wetland conservation practice. Based on discussion under interview by Burera youth community as a group of youth who intervene in Rugezi wetland conservation practice, they highlight such practice of sensitizing Burera local community to join their effort under cooperatives so that they can get any assistance on art and craft development. This is initiated by their practices of buying what local community who are in cooperatives make specifically craft and sell it to tourists. This signifies the easy control of individual who can exploit wetland resources illegal for their interest while the technique of using cooperatives for wetland exploitation highlights the sustainable use of resources so that the future generation can benefit on it.

Local users that were once degrade wetland through agriculture, after restoration their livelihood is also based on revenue sharing. For sustainable wetland conservation there is a need of sharing what is earned due to wetland ecotourism to local community so that they can be aware of protecting it while they know it's important. This statement is mainly delivered in responses of interview addressed to Burera youth community as actors in charge of controlling ecotourism activity that result to wetland conservation, they highlight that for self-engagement of local community on sustainable wetland conservation there is a need of sharing them what is earned specifically investing on small project like green vegetable farm land where all citizen who live near wetland can get vegetables to feed their home, when they see this practice they also understand the importance of wetland conservation rather than destruction. This practice is initiated by Burera youth community under its non-governmental organization known as be wise initiative with aim of protecting Rugezi wetland sustainably through collaboration with local community and local community also benefit from it in economic matters.

Moreover, the livelihood of local users has also benefited in implementation program of some restoration practices, some of them concern making terraces on steep slopes of Buberuka highland and afforestation practice on side of wetland. The local community was among implementers as they were hired to implement all those restoration activities. Therefore, the livelihood of local wetland users after prohibition of agriculture practice is also an opportunity for them to intervene in restoration practice.

IV. CONCLUSION

The community depends on wetlands for a variety of reasons, including fresh water provision, flood prevention, scenic and recreational benefits, etc. However, as demonstrated by the Rugezi wetland, wetlands should be seen as an essential part of long-term livelihood and resource management strategies rather than as resources to be used as temporary fixes to meet food and water shortages..Restoration of Rugezi wetland was initiated by government of Rwanda in 2005 with aim to re-gain degraded ecosystem and stabilize water table as a source of hydro electric power on both Ntaruka and Mukungwa. The impact of efforts to restore Rugezi wetland on local community is more challenging question to answer.Initially,the livelihood of many people in area were directly affected by since they lost acces to land for cultivatiion due to restoration measures. However,the restoration effort appear to startgenerating some benefits to the livelihood of local community. Agroforestry activities and radical terraces have increased crop productivity as there is also a planted grasses on managed terraces and the banks of lakes are providing fodder for liestock , fauna and fllora has also increased in Rugezi wetland and eco-tourists are now visiting the place.

Some of wetland restoration measures have not achieved to its full capacity especially on implementation of buffer distance of the 10m and 50m rule along wetland and at shores of lake due to lack of institutional capacity to oversee, monitor, evaluate and implement the enacted law on wetland conservation.In addition,the high population density of the area and the country reliance on agriculture for the livelihood of local community was considered as a key barrier to the adoptation and implementation of land use measures on wetland managementin the Rugezi wetland. This is mainly caused by the country agricultural policy that encourage the cultivation and drainage of wetland to extend arable land in the country at the same time as different agricultural project in area that is founded y international donors and they had a stake in cultivation of wetlands.

Moreover, Rwanda wetland related policies has strongly prevented deterioration and Loss of these habitats, implementation of strict protective measures, and systematic and ongoing wetland usage monitoring and also existing policies and regulations should be put to implementation. In addition, compliance and enforcement with laws by local Community should be mainstreamed through public awareness, all this should be done through respecting what revised master plan determine on agriculture practice in order to ensure food security and sustainable ecosystem management.

Restoration initiatives must be designed with long-term monitoring and evaluation (>10 years) from the beginning (including planning and budget). This would give stronger support to the long-term effects of wetland restoration, possibly persuade funders of the advantages of such initiatives, and help to determine the long-term most cost-effective intervention types. To identify the precise contribution of the restoration more clearly, this must

incorporate pre-restoration assessment. Primary wetland restoration studies' predictive future value will also be increased by thorough reporting of the original research design and methods as well as the biophysical and socioeconomic context (e.g., wetland type, nearby land use and industries, socioeconomic status of the local population, urban expansion, and development).

Initiatives to protect wetlands should include full participation from the local community. This calls for their understanding of the function of wetlands, the effects of ecotourism development activity on wetland resources, and the initiatives, policies, and laws designed to mitigate wetland degradation and promote the sustainable use of wetlands. As a result, in order to guarantee local population awareness, this study suggests encouraging scientific research on wetland use and management. It also suggests more elaborate projects to increase local community awareness of the wetlands among all age groups, sex groups, educated and uneducated groups. This will facilitate everyone's understanding of, stewardship of, and sustainable use of wetlands and other natural resources. Finally, monitoring and evaluation on different initiated practice related to restoration is needed. This will be efficiently through strong collaboration of both private sector and government not only to evaluate the outcome of restoration on environmental side but also strong consideration on both social and economics livelihood of local wetland users and they should also draw some recommendations in order ensure the sustainability between wetland based restoration practice and to ensure the sustainability in this era of sustainable development as wetland-based restoration approaches must be sustainable, and ecological systems must be balanced with socioeconomic factors. In conclusion, the study advises voluntary restoration with local support rather than extensive migration or forced compliance with outside dictates. Because they are unlikely to work.

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