

Application of Spatial Technologies and Field Techniques to Assess the Status of Wetlands in Lake Kyoga Basin in Uganda

Moses Musinguzi¹

¹Lecturer, Department of Surveying, Makerere University, P.O.Box 7062, Kampala, Uganda
musinguzim@tech.mak.ac.ug

ABSTRACT

Lake Kyoga basin is the largest basin in Uganda with a surface area of 57,233 sq km. The wetlands in this basin are faced with degradation resulting from conversion to agricultural use. This research was undertaken to assess the current status of wetlands in Lake Kyoga basin and mainly the water quality function. The methodology included field measurements on water quality parameters, soil and vegetation. Interviews were conducted with local people living around wetlands and wetland officers in the region. Data generated from field measurements, Global Positioning Systems (GPS) and satellite imagery was entered into a Geographical Information System (GIS) database for further analysis. Results from the analysis indicate that wetlands are still performing the water quality function at varying levels. The capacity of wetlands to perform this function is however affected by the growing number of activities such as rice growing and industrial development. The above results could also indicate the low level of opportunity for wetlands to perform this function given that agricultural methods in the area do not employ inorganic fertilisers and other chemicals such as pesticides.

Keywords: Wetland Assessment, Lake Kyoga Basin, Uganda, Wetland Functions, GIS

1.0 INTRODUCTION

Lake Kyoga basin is the largest basin in Uganda, with a surface area of 57,233 sq km. It comprises of a network of lakes including Kyoga, Kwanja, Bisina and Opeta. In addition, it contains 28 other smaller lakes ranging in size from less than 1sq km to over 100 sq km spread across the northern and eastern side of Lake Kyoga (Lakimo, 2004). The basin is situated between longitudes 32° 10' and 34 ° 50' East, and between 0 ° 20' and 3 ° 40' North . The deepest end of Lake Kyoga is 5.7 metres and its average depth is 3.5 metres (WLD, 2007). The Ramsar definition of wetlands (Matthews, 1993) considers lakes such as Kyoga, whose depth is less than 6 metres deep to be wetlands. However, the Uganda National Wetlands policy adopts a relatively narrower definition of wetlands, which excludes shallow lakes such as Kyoga.

Wetlands in the Lake Kyoga basin provide important products and perform a number of functions such as water storage, filtration and purification, acting as nurseries for fish and sustaining high levels of biodiversity and habitats. To this effect, wetlands in the basin contribute to poverty reduction and directly impact on the livelihoods of the people. However, wetlands in the basin are faced with conversion mainly to agricultural use. By encroaching on wetlands, there is fear that most of the vital functions performed by wetlands will be lost and the negative effects of their loss could be irreversible. This study therefore set out to examine the status of the water purification function in the basin. Water purification includes the removal of nutrients, sediments and organic matters from waters moving through a wetland and is considered to be one of the vital functions for rural populations who depend on wetlands as the major source of water for domestic consumption.

2.0 METHODOLOGY

A combination of methods was adopted for the collection of information on various aspects of wetland functions in the study area. Data was collected over a period of one year from 2006 – 2007. The methods included Mobile GIS and GPS mapping, field measurements, observations and interviews. Analysis was carried out in ArcGIS 9.1.

2.1 Mobile GIS and GPS Mapping

GIS was employed to aid fieldwork planning. A simple database was created in ArcGIS 9.1® (ArcGIS is a trademark of Environmental Systems Research Institute, Inc) software purposely to aid quick data collection by utilising Mobile GIS technology. Mobile GIS is a combination of GIS software, GPS, and mobile computing devices (ESRI, 2004). The Mobile GIS database designed for this work comprised of a layer of Landsat ETM+ imagery, a roads layer and a point layer of proposed observation points linked to an editable data observation form, initially with no records. The satellite image was used for quick identification of wetlands, the Road layer was used for identifying accessibility options, while the handheld GPS was used for both navigation and recording of locations of observation points. This Mobile GIS setup was preferred because it enabled automatic recording of GPS locations against each observation point. A recreational grade GPS such as the one used in this work, may give accuracies between 1-10 metres. This level of accuracy was found to be sufficient for the mapping of wetland observation points for wetland assessment. Furthermore, the automatic recording of locations and direct entry of data into the Mobile GIS minimised errors associated with manual data recording and entry, thereby improving the quality of the data in the database

2.2 Field Measurements

Measurements and observations were carried out at observation point locations determined through purposive sampling. The concept of an observation point or section is adapted from the Uganda National Wetlands Inventory (NWI) (WID, 2000). In the NWI, a section is considered to be a stretch of a contiguous wetland, where wetland vegetation cover is fairly uniform and dominant vegetation species composition can be visually identified by an observer. Observing sections of a wetland system at various observation points ensures a complete description of the ecological, hydrological and other aspects of a wetland system. Observing wetlands by sections suits the wetlands types in Uganda, which have various dominant cover types, are narrow, but extend over a long distance. Many wetland systems in Uganda stretch over several kilometres and cannot be observed at one location.

While at observation points, water quality measurements (pH, Electric Conductivity and temperature) were taken using pH and Electric Conductivity (EC) meters. These parameters have been used successfully for assessing the health of selected wetlands in Lake Edward Basin (Busulwa and Bailey 2004) and Lake Victoria Basin (Woezi *et al.* 1995). Out of these and other previous studies, there is reasonable knowledge on the normal range of values for the variables that are expected from a natural healthy wetland, in Uganda.

For a natural wetland, the normal pH values may vary depending on many factors such as the nature of rocks, soils, wetland ecological composition and landscape position. Optimal values for pH in a natural wetland are expected to be in the range of 6.5-9 (EPA 1990), although many organisms can still survive outside these ranges.

In Uganda, the government institution responsible for setting standards for environmental monitoring, the National Environment Management Organisation (NEMA), allows concentrations strictly within a pH range of 6-8 for discharge in the environment, including aquatic systems (lakes, rivers and wetlands), as well as terrestrial systems. It is considered that the health of species in wetlands is not endangered when the parameters are in the ranges specified. This standard was adopted as a reference for evaluating pH of wetland water in the study area.

In addition to pH, EC was measured across wetlands in the study area. EC is a measure of the ability of water to pass an electrical current, and in wetlands, it is affected by the presence of organic and inorganic dissolved substances like oil, phenol, alcohol and sugar (Myers *et al.*, 2001; Willstedt, 2007). The conductivity of water in rivers generally ranges from 50 to 150 mS/m (Willstedt, 2007) but normal ranges for a natural papyrus swamp is expected to be within a range of 80-150 mS/m (Taylor, 1991) as cited by Wozzi *et al.* (1995). NEMA does not specify any limits on the allowable EC for wetlands, possibly because EC is correlated to TDS, Turbidity or Chloride, which are specified as 1000 mg/l for TDS, 100 NTU for turbidity and 30 mg/l for Chloride. This study adopted the limits 50-150 mS/m as the optimum ranges for EC in a natural healthy wetland.

Variations in water temperature profoundly affect the aquatic life (Kadlec and Knight, 1996). At higher temperatures, gases like oxygen dissolve to a lower extent than in cool water and this affects aquatic animals, as they are weakened by the less availability of oxygen. The temperature limits set by NEMA for discharge of substances in the environment are 20-35 degrees Celsius.

Measurements on soil texture were made using a simple and rapid criteria proposed in the Uganda National Wetlands Inventory Guide (WID 2000). According to the guide, if a soil sample is squeezed in the hand and feels gritty, then it is probably sandy; if it feels soapy, then it is probably silty; if it feels sticky, then it is probably clayey. This finger squeeze method of measurement, though rapid is reliable and suitable for undertaking field-based assessments of soil properties. In wetland rapid assessment, certain parameters require measurement by use of precise instrument such as pH meters. However, other parameters such as land cover, are not easily measured from the field. In this study, the parameters in this category included dominant land cover/land use both in the wetland and surrounding landscape, nature of threats/activities in the wetland and dominant vegetation species. These parameters were measured through visual assessment but the percentage composition of each parameter in each wetland was further verified by interpreting satellite images of the area.

2.3 Informant Interviews

Information about flooding frequency, presence of animals and external pollution sources was obtained by interviewing local people living around the wetlands. Before combining the interview data into the relevant sections of the datasheet, the information would be verified with the Iganga District Environment Officer, who had local knowledge of the area, because of his office and the fact that he is a native of the area. After data collection, initial findings were discussed with the Iganga District Environment Officer and experts from the Wetlands Management Department of the Ministry of Water and Environment. This was done to further explore and verify that the information collected truly reflected the wetland systems in the area.

3.0 DISCUSSION OF FINDINGS

Wetlands are sinks or transformers of suspended inorganic sediments, inorganic phosphorus, nitrate, sulphate, and toxins (Leibowitz *et al.*, 1992). By buffering surface and ground waters from these pollutants, wetlands play a significant role in maintaining water quality within a watershed (Brinson, 1988). Within the study area, the average pH of water samples taken from wetlands was found to be 7.26 ± 0.85 , while the computed average temperature was $24.5^{\circ}\text{C} \pm 3.16$ (see Table 1), and the average EC was calculated at 269.66 ± 198 . Clearly, the mentioned values are within the safe ranges set by the National Environment Management Authority in Uganda as discussed in the previous section.

Table 1: Descriptive statistics for pH, EC and Temperature for Wetlands in Lake Kyoga basin

Variable	Mean	SD	Range	max	min
pH	7.26	0.85	5.97	10.54	4.57
EC	269.66	198.92	960.8	971.00	10.20
Temperature	24.50	3.16	15.00	34.00	19.00

The results in Table 1 suggest that water in the basin is generally not polluted with hazardous materials. Although, this may be interpreted as a result of the role of wetlands in performing the water quality function, it could also suggest that the level of discharge of pollutants into the wetlands is not significant to alter the water quality parameters beyond acceptable limits. This assertion is equally supported by field observations, in which it was identified that most wetlands were surrounded by scattered small agricultural fields. This traditional type of agriculture in rural areas does not involve use of inorganic fertilisers and other chemicals such as pesticides. Furthermore, the landscape is characterised by sparse settlements with minimal discharge of household chemical wastes such as detergents. Besides the above factor, the level of industrialisation in the area is still low.

These results demonstrate a situation where wetlands within the basin are being degraded and hence diminishing their capacity to perform water quality functions. However, because the opportunity for the wetlands to perform water quality function is still limited, the measured parameters still show normal ranges.

Furthermore, although the average pH for the entire basin was found to be in the acceptable normal range, its spatial distribution was not uniform within the basin. The spatial variations

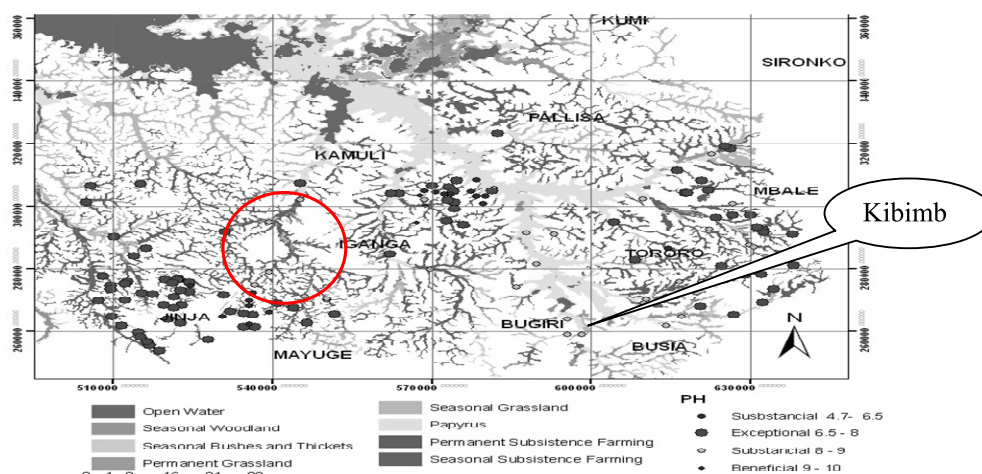


Figure 1: Spatial Distribution of pH in the study area

in pH values were analysed through the use of GIS and are displayed in Figure 1. In the map, the pH values have been classified as Beneficial, Substantial and Exceptional so as to emphasize their relative importance for the water quality status in a wetland. The classification is based on the deviation of the values from acceptable pH values for normal wetlands as established by NEMA. The Beneficial class includes values that are tending towards either acidity or alkalinity, and hence are relatively less desirable. The pH values assigned to this class are 9.0 - 10.5 and 4.0 - 4.5. The Substantial class includes values that are less acidic or less alkaline, and are hence closer to the acceptable range. The values in the class range from 4.5 - 6.5 and 8.0 - 9.0. Finally, the Exception class includes the acceptable pH values of 6.5 - 8.0.

Observation points along the Malaba-Mpologoma-Manafwa system from Busia/Bugiri showed slightly less than normal values and this could be attributed to pollution from Kibimba rice fields as indicated on the map, and the effect of effluents from Tororo and Mbale towns. Similarly, the upper section of Lumbuye system (encircled), shows slightly less than normal values than the surrounding wetlands. This could also be attributed to rampant mechanised large scale rice growing in the area, which is in the offing. Observations on the permanent section of the Lumbuye system downstream show an improvement in the pH values and hence signifying that the intact section of the wetland is performing the nutrient removal function.

Like pH, the electrical conductivity has been classified to reflect the importance of EC values for wetland water quality function. Values 1- 50 and 500-1000 are classified as Beneficial, values 150-500 as Substantial and optimum values 50-150 as Exceptional. The spatial distribution of electrical conductivity in the study area shows a general increment of values from Jinja towards Tororo in a west-east direction (*see* Figure 2).

It is not clear what this trend represents, but could be attributed to both the rock and soil types. Another observation is that the improved EC downstream on the Malaba-Mpologoma - Manafwa wetland system (Busia-Bugiri arm) is an indication that some of the pollutants do not reach the lake, hence confirming the role of the wetland in removing the materials. However, a more detailed investigation is required to substantiate these findings.

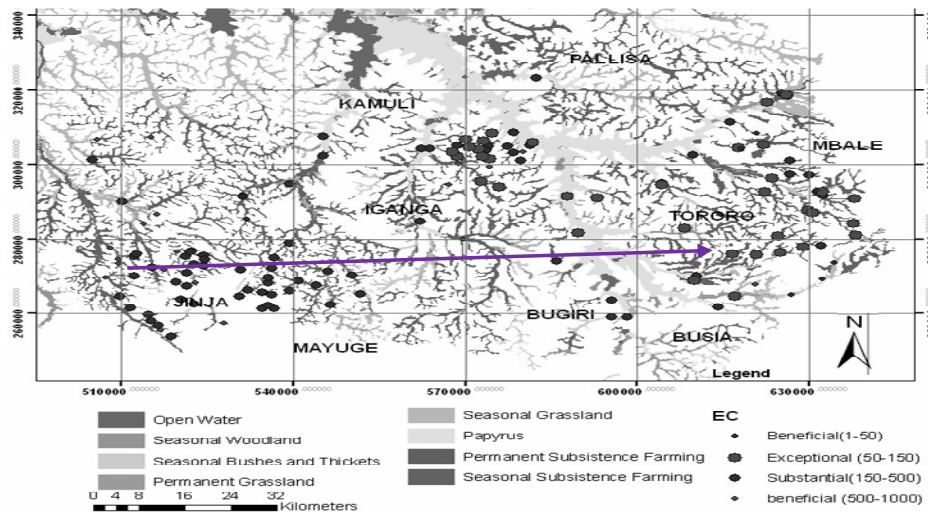


Figure 2: Spatial distribution of Electrical Conductivity in the study area

To understand the spatial trend of water quality in the basin, four profiles were taken along the main wetland systems (*see* Figure 3). One profile was taken along Lumbuye (labelled as Profile 1), the second profile was taken along the Naigombwa arm of Malaba-Mpologoma-Manafwa system (labelled as profile 2), the third profile was taken along Tororo-Busia arm of Malaba-Mpologoma-Manafwa system (profile 3) and the last profile along the Mbale arm of Malaba-Mpologoma-Manafwa system (profile 4).

Along Lumbuye system (profile 1), no definite spatial trend can be deduced by plotting temperature and pH against distance from the head waters of the basin. One observation however is that temperatures are slightly higher in the upstream wetlands (30°C) and generally decrease (until 20°C) as one advances towards the permanent wetland near the main waters of the basin (*see* Figure 4A).

This could be explained by a combination of reasons: In the first instance, it could be due to the small sizes of wetlands in the region, whose waters are detached from the main water of the basin. Secondly, loss of vegetation cover through cultivation in the wetlands exposed water, and therefore direct heating of wetland water by the sun, is likely to contribute to a temperature rise. Thirdly, direct heating of exposed bare soil is likely to have raised the temperatures of wetland water through radiation and conduction of ambient heat from the hot soil. Similarly, in the permanent section of the wetland system, the lower temperatures could be explained by the presence of dense vegetation cover (papyrus and typha) and the fact that the water is directly linked to the larger waters of the basin.

The trend of pH from upstream to downstream showed small variations, but kept within the normal range. As mentioned in the above section, this could be explained by limited use of chemicals in the surrounding landscape hence exerting less opportunity on the wetlands. However, as settlements become denser (as seems to be the trend) and use of chemicals increases in the neighbouring landscape, it is expected that the water quality will deteriorate. In the Naigombwa wetland system (Figure 4), spatial trends in the water quality parameters

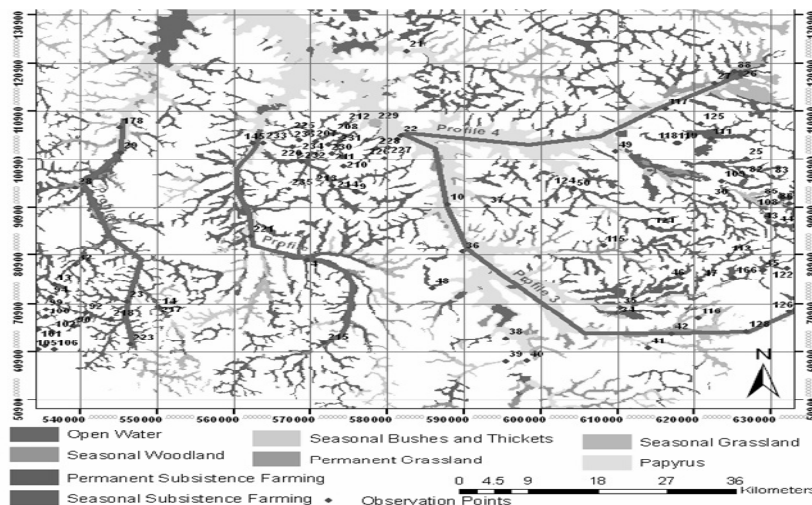


Figure 3: Spatial locations of pH profiles on the major wetland systems

are not explicit. However, it can be observed that the temperatures decrease towards the main waters of the basin, just the same way as it was observed in the Lumbuye system. The pH remains stable within the normal range, possibly because of similar reasons as in the Lumbuye system. The two profiles, taken along Malaba-Mpologoma-Manafwa system in Figure 4 C and D show slightly different and unique spatial trends in temperature. The pH in the two sub-systems remains fairly stable within the normal range, showing small variations at different distances from the main waters. The existence of variations in water quality trends for the four wetland systems as demonstrated above, is an indication that wetlands in different landscape conditions do not function in a similar way. This further supports the assertion that performance of wetland functions cannot be generalized over a watershed, but rather through individual wetland assessment.

4.0 CONCLUSION

Through GIS analysis, field measurements, observations and interviews, an assessment of wetland functions in the study area has been accomplished. Although the water quality parameters are still within normal ranges, this does not necessarily indicate that wetlands are still in good health. Rather, this may indicate that the opportunity for wetlands to perform functions is still low as a result of limited use of inorganic fertilisers and other chemicals such as pesticides. As the population increases and agricultural practices change, it is expected that the negative effects of lack of wetlands will be more appreciated. Finally, these results

demonstrate that meaningful interpretation of wetland assessment results requires examination of both wetland functions and opportunities.

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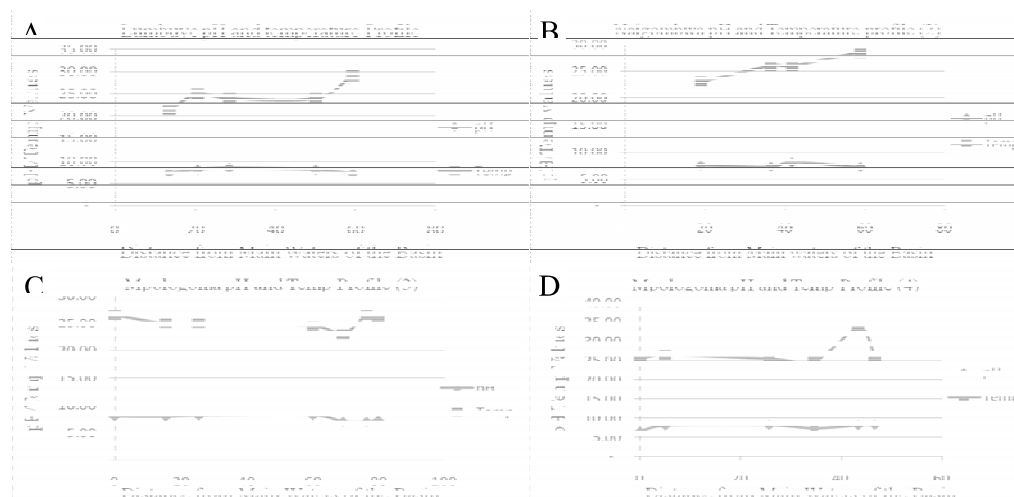


Figure 4: pH and Temperature profiles along the major systems in the study area (dist in km)

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