Policy Brief

APRIL 2021

Eutrophication of Lake Victoria - Restoring the former glory by control of excess nitrogen discharge in the basin

IMPACTS OF EUTROPHICATION IN LAKE VICTORIA

- Water hyacinth infestation of the lake
- Hindrances to transportation and fishing
- Growth of dense algal blooms
- Water quality degradation
- Development of hypoxic zones - leading to fish mortalities

Lake Victoria is Africa's largest freshwater body with a surface area of ca. 68,000 km^2. It is shared by Kenya (6%), Tanzania, (49%), and Uganda (45%) while Rwanda and Burundi forms part of its drainage basin. The Lake is of great socio-economic and ecologic value not only in Eastern Africa but also in the Nile basin countries. It supports a fast growing population estimated at 45 million people (World Bank, 2018). The functions of the Lake in the region ranges from provision of basic needs and services (food, fresh water, and transport) to economic resources like hydroelectric power, commercial water, wildlife and tourism, minerals, cash crops, trade, industry, and fishery. In addition, it is the source of the White Nile River.

However, Lake Victoria's ecosystem health has tremendously degraded in the last five decades due to eutrophication. Eutrophication is the biological effect caused by nutrient enrichment in aquatic ecosystems. In the Lake Victoria, eutrophication is manifested by the growth of dense algal blooms and water hyacinth infestation (Fig1). It is also associated with the development of hypoxic zones which leads to fish mortalities, and this has been recently reported in Lake Victoria (KNA, 2021). One of the key nutrients causing eutrophication are nitrogen species such as nitrate. In addition, in terms of human health, high nitrate uptake is a risk of methemoglobinemia (blue baby syndrome), it causes birth defects in children, while long term exposure pose a risk to cancer (Brender et al., 2013; Kendall et al., 2007). The World Health Organization (WHO) has put the maximum allowable NO_3- concentration at 50 mg L^{-1} in drinking water.

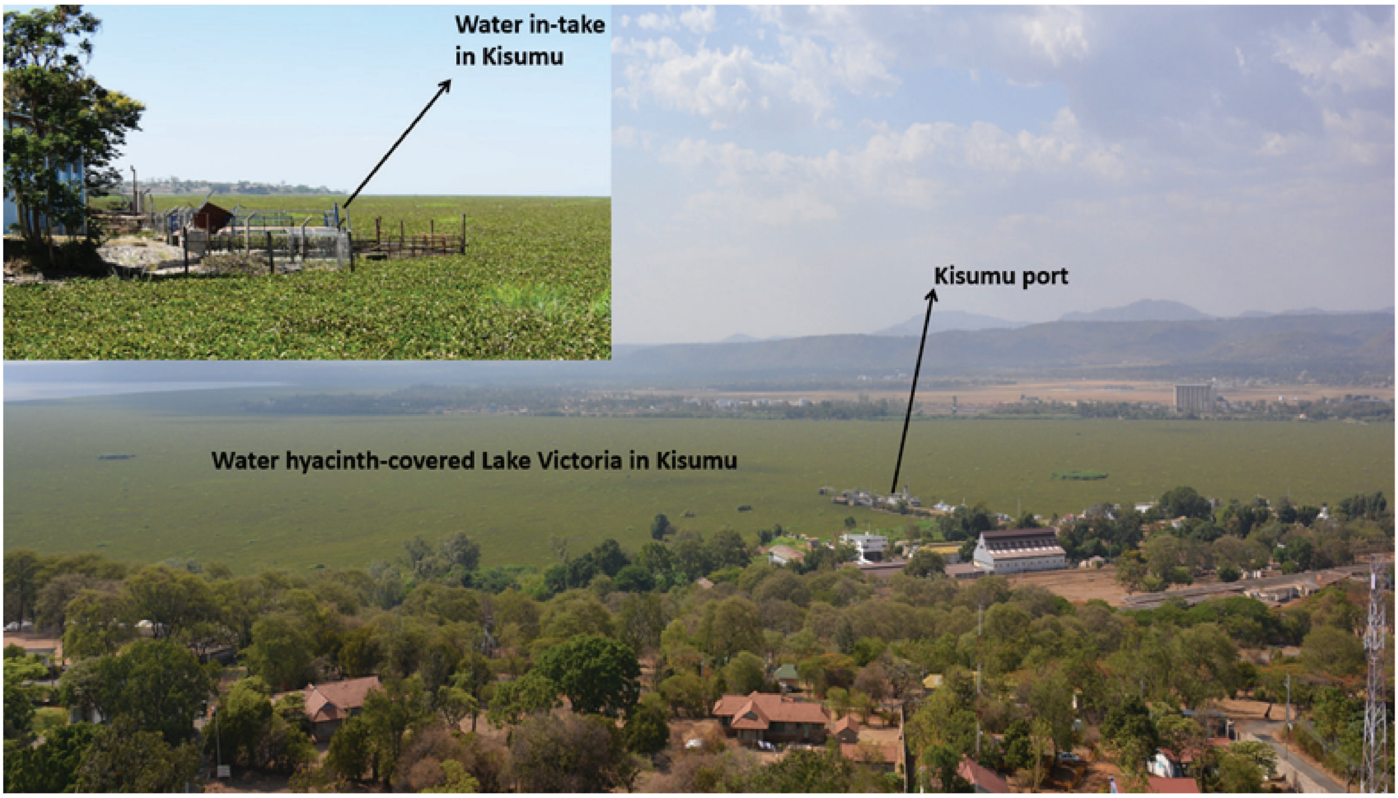

Figure 1. Water hyacinth-infested waters of Lake Victoria at the Kisumu bay (Courtesy P. Boeckx, February 2017).

Whereas the effects of eutrophication in the Lake Victoria basin are well pronounced, studies have associated it to high human population growth, land use change and economic activities being witnessed in the basin during last few decades (Juma et al. 2014). However, scientific information and data on the sources of key nutrients associated with eutrophication in the basin is very scarce. Previously, the Lake Victoria Basin Commission (LVBC) through the Lake Victoria Environmental Management Project (LVEMP) has conducted water quality studies in the basin. However, their data is limited quantitatively and qualitatively. Furthermore, recent nutrient data is rare, while studies focussing on nitrate discharge and its potential sources is lacking. This major information gap has complicated targeted intervention measures by environmental and water resources management institutions to control eutrophication. Therefore, the current study investigated river nitrate discharge, distribution and potential sources in three major river basins (Nyando, Nzoia and Sondu Miriu) draining into the Lake Victoria.

Study findings

River nitrate concentrations

Nitrate concentrations varied spatially in the three river basins. The mixed agriculture land use of the Nyando basin recorded the highest nitrate levels (Fig. 2 & 3). This land use is characterised by mixed farming of food crops, livestock and a commercial flower farm. Significantly high nitrate concentration ranging 23 - 56 mg L^{-1} was obtained in a stream located downstream of a commercial flower farm (Fig. 3). In addition, the urbanized areas of the Nzoia basin and the large-scale tea estates of the Sondu Miriu basin recorded highest nitrate concentrations for their respective river basins (Fig. 2). On the other hand, upstream areas of the river basins characterized by forests and small scale tea farms recorded low nitrate concentrations. This reveals the influence of land use on river nitrate concentrations, i.e. nitrate concentration increases with human population density and intensity of land use activities.

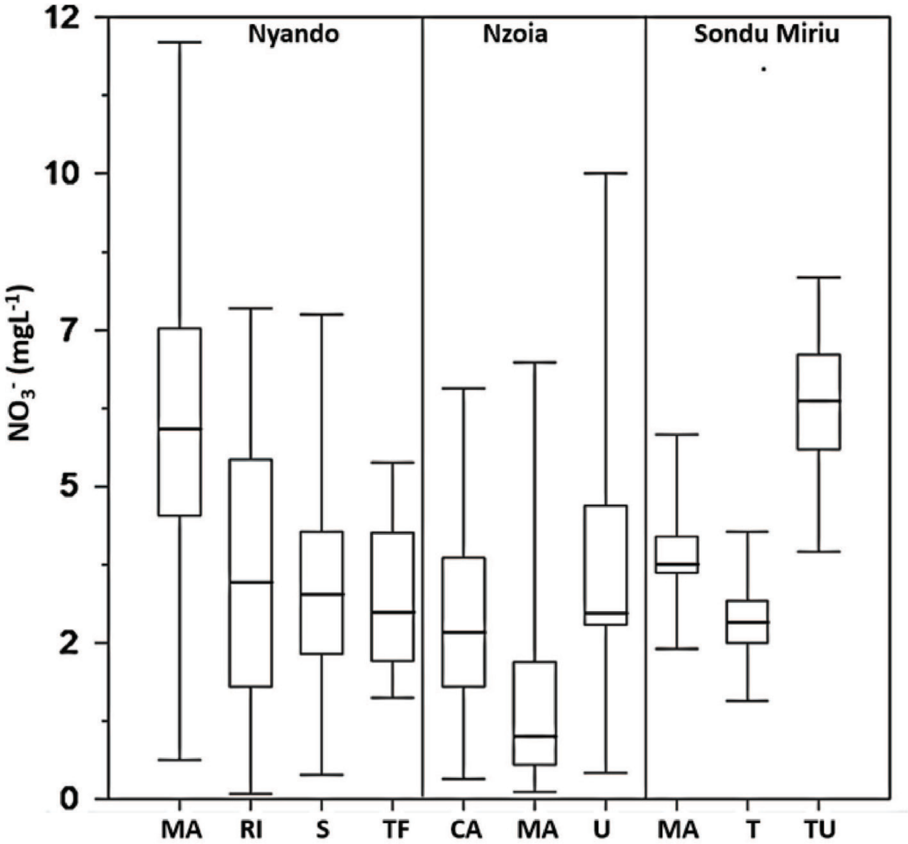

Figure 2. Spatial variation of nitrate concentration in the three major river basins draining into Lake Victoria. MA: mixed agriculture; RI: residential & industrial; S: sugarcane; TF: tea & forests; CA: commercial agriculture; U: urban; T: tea; TU: tea & urban. Boxplots represent 25th, 50th, and 75th percentiles, whiskers represent 5th and 95th percentiles.

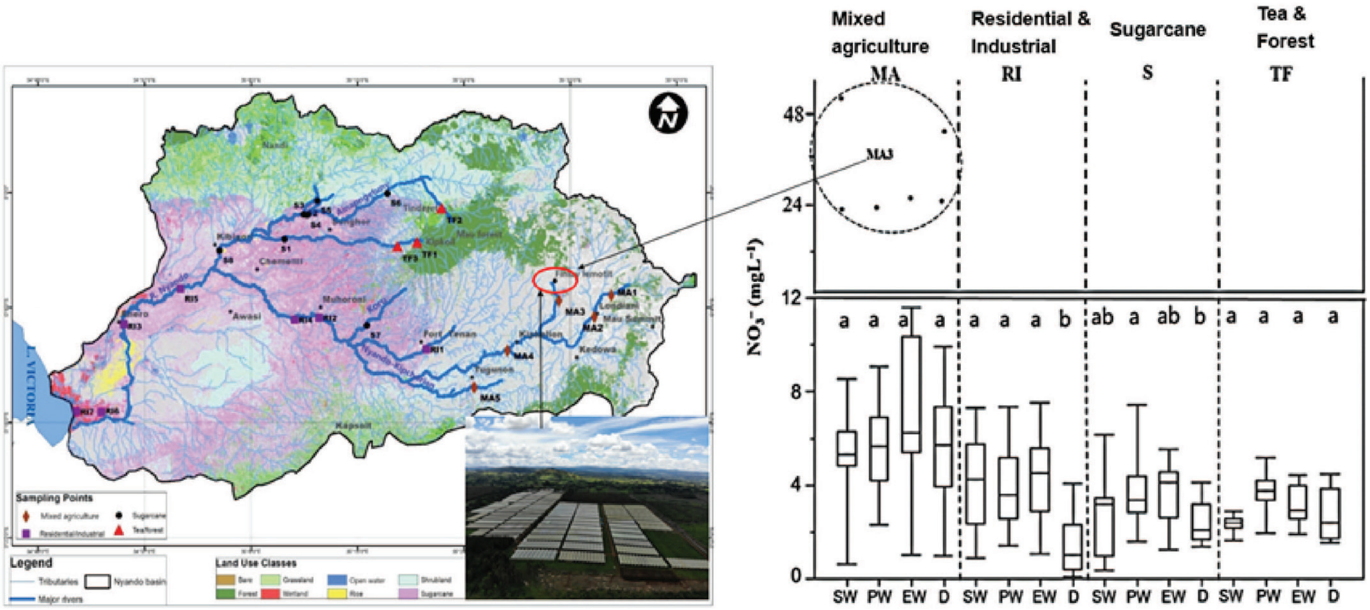

Figure 3. Spatio temporal nitrate concentration in the Nyando river basin. Significantly high nitrate levels were obtained in "MA3", located downstream of commercial flower farm. Seasons are SW: start of wet; PW: peak wet; EW: end of wet; D: dry.

Nitrate delivery into Lake Victoria is controlled by water discharge volume, basin size, and season (Table 1). The Nzoia River discharged the highest nitrate levels into the Lake followed by Sondu Miriu and Nyando rivers in that order. The wet seasons exhibits the highest nitrate delivery into the Lake.

Table 1. Water and nitrate discharge into the Lake Victoria by the Nyando, Sondu Miriu and Nzoia rivers during the start of wet, peak of wet, end of wet and dry seasons.

Season	Nyando (3,590 km²)		Sondu Miriu (3,508 km²)		Nzoia (12,709 km²)	
	Water discharge ($m^3 s^{-1}$)	Nitrate discharge ($kg day^{-1}$)	Water discharge ($m^3 s^{-1}$)	Nitrate Discharge ($kg day^{-1}$)	Water Discharge ($m^3 s^{-1}$)	Nitrate discharge ($kg day^{-1}$)
Start of Wet (March)	4.0	**800**	6.1	**2,300**	41	**17,700**
Peak Wet (May)	37.4	**6,200**	22.9	**7,200**	187	**22,200**
End of Wet (Sept)	8.7	**1,500**	16.2	**5,300**	149	**33,500**
Dry (Dec)	3.0	**60**	8.9	**2,600**	26.6	**5,200**

Sources of nitrate pollution to surface water

Information on the sources of nutrient pollution in the Lake Victoria basin is highly lacking especially concerning non-point pollution sources, and this study provided pioneering data and information on the potential nitrate sources in the basin. Through the application of hydro-chemical, isotopic and modelling (mixSIAR) methods, this study revealed that manure and sewage were the dominant sources of river nitrate discharge, and especially in the mixed agriculture, sugarcane, and residential and industrial land use areas (Fig. 4). These land uses are characterized by highly populated areas, mixed farming of food crops and livestock, urban centers and agro-based industries. Manure application in farming is regular, free-range livestock keeping is the common husbandry method, while major towns and industries lack adequate sanitation network and sewage treatment systems (Nyilitya et al., 2021).

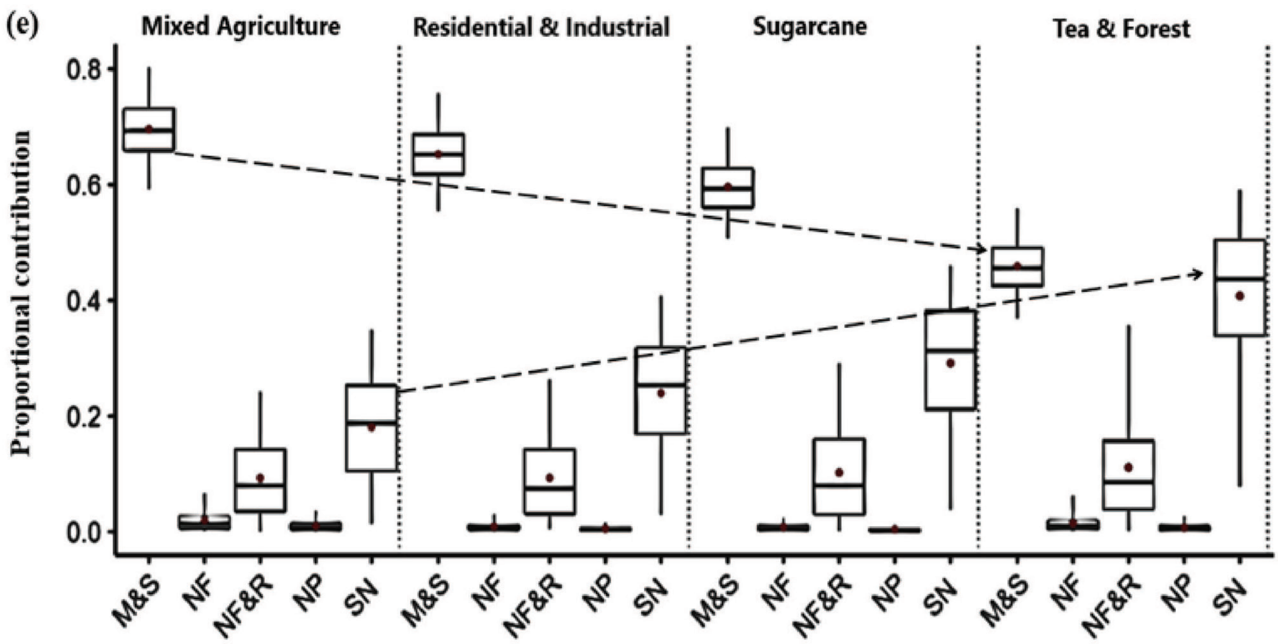

Figure 4. mixSIAR model estimation of proportional contributions of local nitrate sources in the Nyando basin per land use type. Potential nitrate sources are manure & sewage (M&S), nitrate fertilizer (NF), Ammonium in fertilizer and/or rainfall (NF&R), nitrate in precipitation (NP), and soil nitrogen (SN).

The study further revealed that sewage was the dominant nitrate source in the urbanized and industrialized areas of the Nzoia and Nyando rivers (Nyilitya et al., 2020). Soil nitrogen was the other important source of river nitrate, especially in the upstream catchments characterised by forests and small-scale tea farms. Seasonally, the soil nitrogen contribution was relatively higher in the wet seasons, which also recorded high turbidity in the rivers and the Lake. This is an indicator of high soil erosion rates induced by deforestation, poor farming practices, and encroachment of wetland and riparian areas. On the other hand, inorganic fertilizers significantly contributed to river nitrate input in the commercial tea and commercial flower farming areas. In addition, inorganic fertilizer contribution was substantial in the agricultural land uses during the wet season.

Findings of this study highlights the negative impacts of anthropogenic activities taking place in the basin, which includes land subdivision into smallholder farms, forest and wetland encroachment, development of commercialized agriculture, urbanization and industrialization. These have led to serious negative environmental impacts on the basin such as deforestation, accelerated soil erosion, incremental wetland loss, and elevated sewage discharges that triggers uncontrolled discharge of nitrates into the Lake resulting in eutrophication of the Lake waters.

Interventions and policy measures

(1) Development and implementation of manure use guidelines. This will optimize manure use in agriculture and at the same time ensure water resources quality.

(2) Implementation of animal husbandry methods which controls the spread of animal wastes- like paddocking and zero grazing.

(3) Development and implementation of fertilizer use and management guidelines, e.g. application of the 4R nutrient concept.

(4) Technological advancement and expansion of the existing sewerage networks and waste water treatment infrastructure.

(5) Improvement and control of water treatment by agro-business industries in the basin.

(6) Resettlement of smallholder farmers from forest reserves and wetlands

(7) Enhancement of tree planting, wetland and riparian zone restoration.

(8) Enhancement of existing environmental and water resources management regulations; for instance, restricting the direct watering of livestock in surface water.

(9) Enforcement of the existing land and water resources policies -which clearly define forest reserves and riparian areas as protected land and free from human activities.

(1) Free range livestock keeping and direct watering of animals in rivers

(2) Deforestation and biomass burning | *(3) Soil erosion and wetland encroachment* | *(4) Poor sewage management* | *(5) Proliferation of slums and poor sanitation*

Figure 5. Key anthropogenic activities fueling excess nitrate discharge in Lake Victoria basin.

Acknowledgments

This study was conducted by Ghent University and the University of Nairobi with TEAM Project funding No. ZEIN2016PR423 from the Flemish Interuniversity Council (VLIRUOS), Belgium. We also acknowledge the Ministry of Water, Sanitation and Irrigation (Kenya) for the human resources support.

Technical guidance for this work contributed by:		
Prof. Pascal Boeckx Isotope Bioscience Laboratory – ISOFYS, Department of Green Chemistry and Technology, Faculty of Bioscience Engineering, Ghent University, Belgium	and	**Dr. Stephen Mureithi** Department of Land Resource Management and Agricultural Technology Faculty of Agriculture University of Nairobi, Kenya

References

Brender, J.D., Weyer, P.J., Romitti, P.A. et al., 2013. Prenatal nitrate intake from drinking water and selected birth defects in offspring of participants in the national birth defects prevention study. Environ. Health Perspect. 121, 1083–1089.

Juma, D.W., Wang, H., Li, F., 2014. Impacts of population growth and economic development on water quality of a lake: Case study of Lake Victoria Kenya water. Environ. Sci. Pollut. Res. 21, 5737–5746.

Kendall, C., Elliott, E.M., Wankel, S.D., 2007. Tracing anthropogenic inputs of nitrogen to ecosystems, in: Michener, R., Lajtha, K. (Ed.), Stable Isotopes in Ecology and Environmental Science, Blackwell Publishing Ltd., Oxford, UK, pp. 375 – 449

Kenya News Agency, 2021. www.kenyanews.go.ke/research scientist terms fish deaths in Lake Victoria normal occurrence, 11/02/2021.

Nyilitya, B., Mureithi, S., Bauters, M., Boeckx, P., 2021. Nitrate source apportionment in the complex Nyando tropical river basin in Kenya, Journal of Hydrology, 594, 125926

Nyilitya, B., Mureithi, S., Boeckx, P., 2020. Land use controls Kenyan riverine nitrate discharge into Lake Victoria – evidence from Nyando , Nzoia and Sondu Miriu river catchments. Isotopes Environ. Health Stud. 56, 170–192.

WorldBank, 2018. Lake Victoria Environmental Management Project: Project Information Document/Integrated Safeguards Data Sheet (PID /ISDS). World Bank 21

Correspondence

Dr. Benjamin K. Nyilitya
National Water Resources Department – Water Research Division
Ministry of Water, Sanitation & Irrigation, Maji House, Nairobi
P O Box 49720-00100, Nairobi.
Email: kyalob73@yahoo.com

University of Nairobi

GHENT UNIVERSITY

Republic of Kenya
Ministry of Water, Sanitation & Irrigation

vliruos SHARING MINDS, CHANGING LIVES