Research Application Summary

An overview of pollution loading into Lake Kivu basin

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Abstract

Increasing pollution loading is one of the factors which have led to instability of the Lake Kivu threatening the survival of millions of people living around it. This study will i) characterise and quantify historical land use and livelihood changes in the Lake Kivu region, ii) estimate pollution load from different sources into the Lake and iii) identify the best management options for reducing point and non-point pollution loading into Lake Kivu. Qualitative, quantitative and modeling approaches are being used. The major outputs of the study include increased understanding of the factors and processes driving changes, land-use/cover and livelihood trajectories since 1974, tools to predict future conditions, hotspot of sediment and nutrient export into the Lake, evidence based recommendations to inform future management decisions aimed at conserving and restoring the natural and human environments of the Lake Kivu basin. This study has just been initiated.

Key words: D.R. Congo, estimation, Lake Kivu, load, water pollution

Résumé

L'augmentation de la décharge polluante est l'un des facteurs qui ont conduit à l'instabilité du lac Kivu menaçant la survie de millions de personnes vivant dans ses environs. Cette étude permettra i) de caractériser et de quantifier les changements de l'utilisation historique des terres et des moyens de subsistance dans la région du lac Kivu, ii) d'estimer la charge polluante provenant de différentes sources vers le lac et iii) d'identifier les meilleures options de gestion pour réduire la décharge de pollution ponctuelle et non ponctuelle dans le lac Kivu. Des approches qualitatives, quantitatives et de modélisation sont utilisées. Les principaux résultats de l'étude comprennent la compréhension approfondie des facteurs et des processus expliquant les trajectoires des changements, de couverture/utilisation des terres et de moyens de subsistance depuis 1974, des outils pour prédire les conditions futures, les points chauds d'exportation des sédiments et des nutriments vers le lac, des

recommandations fondées sur des preuves pour informer les futures décisions de gestion visant à conserver et à restaurer les milieux naturels et humains du bassin du lac Kivu. Cette étude vient juste d'être lancée.

Mots clés: RD Congo, estimation, lac Kivu, charge, pollution de l'eau,

Background

Land and water quality degradation is still widespread and reported to be increasing globally causing *inter-alia* declining crop yield, increasing water rehabilitation costs (Lal, 1988b; Sanders, 1992; Magunda and Tenywa, 2001). Although the cause-effect inter-relationship of soil and water pollution is generally recognised, there is a paucity of data on the magnitude of the phenomenon in the Lake Kivu Basin, the link to current land-use/cover and its management, the contribution of point and non-point source and atmospheric deposition to the current observable load (Majaliwa *et al.*, 2009).

Lake Kivu basin is among the most fragile and highly sensitive ecosystems in the region. It possesses a unique type of flora and fauna of global interest. It covers approximately 7800 km^2, with numerous small rivers and streams flowing into it, and one major outflow Ruzizi emptying into Lake Tanganyika southwards. It is characterised by a great range of vegetation cover from grasses interspersed with trees, deciduous forest, savannah mosaics and woodland in some areas, and a high susceptibility to changes in land use. The region has experienced in the past decade political instability, refugee migration and civil war, large-scale land clearance to satisfy energy demand, construction and timber harvesting from neighboring countries and from within, and most especially for agricultural purpose (Majaliwa *et al.*, 2009); exacerbating therefore soil erosion and pollution related loadings into the fresh surface waters and lake Kivu in particular (Jorgensen *et al.*, 2004).

Lake Kivu is one of the three known exploding lakes due to its content in carbon dioxide and methane and is characterised by millennial timescales violent vegetation turnovers. The primary production in meromictic Lake Kivu is sustained by external nutrient inputs and by internal loading due to upwelling caused by sub-aquatic sources (Muvunja *et al.*, 2010).

Since the measurements in the 1970s, 14CCH4 and ä13CCH4 changes indicate that methane produced from organic material has increased (Pasche, *in press*); saturating 40% of the Lake. With the expected demographic pressure and its associated loading increment coupled with punctual volcanic induced impacts, the Lake is likely to rapidly reach a critical status, increasing the risk of a catastrophic explosion of the deadly gases which could be triggered by lava flows, earthquakes, landslides, storms or industrial waste (Cotel, 1999). The increasing sediment and nutrients loading pose also a severe threat to biodiversity (Halbwachs, *et al.* ,2002) and the stability of the Lake basin (Cohen *et al.*, 1993; Cohen, 1995, Donohue *et al*., 2003) as crop yields are also reported to be declining (Tenywa *et al.*, *in press*).

Participative identification of best management practices is thus very important for pollution abatement (lake stability) and crop yield enhancement for small scale farmers of Eastern D.R. Congo who are just emerging from a decade of civil war.

Objectives

This study has three broad objectives:

- Characterise and quantify historical land use and livelihood changes in the Lake Kivu region.
- Estimate pollution load from different sources into Lake Kivu
- Identify the best management options for reducing point and pollution loading into the Lake Kivu

Literature Summary

Magnitude of soil degradation. Soil degradation due to poor management is reported to have reached catastrophic proportions on agricultural lands in East and Central Africa and particularly eastern D. R Congo and Rwanda (Majaliwa, *et al.*, 2009; Tenywa *et al.*, 2010). The impact of land use on water quality is readily inferred from the vast accumulation of literature (Smith *et al.*; 1987; Sharpley *et al.*; 1991). Generally, a portion of runoff and sediment generated from different land-uses including croplands always ends up in drainage networks (Johnes, 1996). It is recognised in similar ecosystems in the world, that agriculture is the major contributor of sediment and nutrient load (Raymond, 1984; Neely and Baker, 1989; Strebel *et al.*, 1989; Power and Schepers, 1989; Lehman, 1993; Rekolainen, 1993; Calamari *et al.*, 1994). Boostman and Heckey (1993) observed that nutrient load increases were associated with increased burning and soil erosion, emphasizing the role played by the land-use systems and management in the deterioration of the quality of the water bodies and their tributaries (Cole *et al.*, 1993; Peierls *et al.*, 1991; Field-Juma *et al.*, 1995).

Cost of land degradation. The economic cost of off-site and on–site soil erosion-associated degradation is always very high. Therefore, unless major agricultural non-point contributing areas and other soil erosion hot spot areas are identified and urgent control measures are put in place, small holder's capacity to increase food production and alleviate poverty will be undermined leading to vicious cycle of increasing poverty and land degradation (GTZ, 1995).

Factors controlling pollution loading. Land use is an important factor controlling the magnitude of terrestrial pollution from soil erosion and soil nutrient losses (Wood, 1986; Thomas *et al.*, 1992). Inappropriate allocation of land utilisation types is one of the major causes of soil erosion related water pollution (Mokwunye *et al.*, 1996). Annual crops, such as maize that increase susceptibility of an area to erosion, are in many cases grown on very steep slopes. Unfortunately cultivation on very steep slope is more often coupled with poor land management, such as lack of erosion control structures, overgrazing, and burning (Lal, 1988b; El-Swaify 1982, 1994; AID, 1988; Meybeck *et al.*, 1989; Pimental *et al.*, 1993; Bhusham *et al.*, 1994; Zake *et al.*, 1995).

Best management practices. Good soil and crop management measures require an understanding of the hydrology, soil, farming system, topography, and socio-economic factors (Pereira *et al.*, 1962). Several land management practices have been introduced in the region, however, they are characterised by low uptake (Achan, 2002).The adoption of best management practices follows the 'diffusion of innovation' process pathway which is influenced by the nature of the practice, communication channels, time and the social system (Rogers, 2003).

Study Description

The river Lwiro is located on the eastern flank of Lake Kivu, between latitudes 2°15' and 2°30' S and longitudes 28°45' and 28°85' E. Its headwaters are in the Kahuzi-Biega National Park mountain region, at an altitude of 2000 m. The soil comprises clay and rich volcanic soil, which is easily eroded. The geological composition is of Precambrian metamorphosed sediments (metamorphic rocks) and Precambrian metamorphosed sediments (Cohen and Lepersonne, 1967). Verhaeghe (1964) describes metamorphic limestone and numerous travertines along Lake Kivu and Lake Edward. Carbonates for the production of cement are also found north and north-west of Lake Kivu. The Lwiro River is approximately 27.2 Km long and has a mean width of 7 m (Bagalwa, 2006).

Land-use/cover mapping. Landsat images will be used to reconstruct the land use history from 1974 to date. A time series of Landsat images (1974, 1986, 1996 and 2011) taken during the same period of the year will be acquired and analysed using Erdas imagine. In addition to Landsat images a series of ancillary data (aerial photos taken around 1959, interviews, desk reviewed information) will be consulted for additional historical perspectives and strengthening the image analyses. Images from the same time of year will be obtained in order to curtail classification errors due to seasonality for old images. Recent images will be used for testing the sensitivity of the analyses to seasonality, since they have a relatively continuous coverage. Existing land cover maps of the area (such as the GLC2000, Africover, and USGS maps) will be used as a source of qualitative validation / assessment. Supervised and unsupervised classification procedures will be implemented to classify the Landsat images into the established land uses. A sample of pixels will be selected and then visited (or vice-versa), in order to build a confusion matrix. The kappa index of agreement statistical test of the classification accuracy for the whole will be determined.

Land-use/cover dynamics. Land-use/cover spatio-temporal dynamics will be assessed using the land-use cover change modeler software, and regression techniques.

Livelihood change characterisation. Livelihood change will be characterised using semi-structured questionnaire and group discussion. A total of 200 household heads will be randomly selected in Lwiro micro-catchment and interviewed. Focus group discussions will also be conducted. Questions will focus on past and current livelihood indicators such land-use, soil productivity/fertility, fish production, socio-economic conditions and constraints to improved livelihood, and existing best management strategies. In addition, 10% of the interviewed households will be subjected to household analysis. All the socio economic data will be entered in and analysed Statistical Package for Social Scientists version 12.

Estimation pollution loading into Lake Kivu. Both point and non-point pollutions will be estimated. The generated nutrient loads in point sources derived from domestic, industries and business activities will be estimated respectively using population, production and basic units. These are divided into two categories: one discharged into the drainage system and the other removed by treatment facilities. Point source runoff nutrient loads will be estimated regularly in the field. In addition water quality parameters will be measured at different location of the river. Wet and dry deposition of P, K and N will be estimated using field measurements. Atmospheric deposition collectors will be installed at four sites in the basin. In addition regional data will be collected interpolated and validated using data collected from the four sites. ArcSWAT model will be calibrated and validated using field information, and simulation will then be run to identify the micro-catchment hot spot areas.

Determination of the best management practices Best TADs management strategies. Best management practices will be identified using semi-structured survey and field experimentation. A focus group discussion will be conducted in the hotspot area to identify the perceived best land management practices that will be tested in the field for three seasons using runoff plot approach. Performance of a technology will be assessed using soil, runoff and nutrient losses (soil organic matter, phosphorus, potassium, calcium, sodium, magnesium and nitrogen). The total soil and runoff losses during a given season will be determined by summing up the different values obtained after each storm for the period covering that season (15^{th} March-15^{th} July for long rains, 1^{st} September-31 December for short rains). Analysis of variance will be performed on the data using Genstat discovery version.

Achievements

- 36 Runoff plots have been established in two agricultural land-uses (Annuals and perennials)
- One staff gauge has been installed on Lwiro river, 100 m from its outlet into Lake Kivu
- Livelihood change characterisation is being conducted in six villages around the south-western part of Lake Kivu.

This study is entrenched in the field of hydrological modeling and livelihood studies. Pollution loading estimation into Lake Kivu will be very useful in understanding the lake nutrient dynamics, ecosystem stability, while livelihood change outputs

Establishment of runoff plots in Lwiro micro-catchment.

Staff gauge installation on Lwiro river.

can be valuable in micro socio-economic household modeling and survival studies.

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References

APHA (American Public Health Association), 1981. Standard methods for the examination water and wastewaters, 15^{th} Ed. Washington, D.C.

Azanga, E., Majaliwa, J.G.M. and Kansiime, F., 2011. Sediments and nutrients hotspot areas dynamics in selected micro-catchments of the Lake Tanganyika basin in Democratic Republic of Congo. *Second RUFORUM Biennial Meeting 20 - 24 September 2010, Entebbe, Uganda.* pp. 579 - 584.

Bagalwa, M. 2005. Environmental impact of land use change on water quality of inflowing tributaries of Lake Kivu. In E.Odada, D Olago, W. Ochola, M. Ntiba, S. Wandiga N. Gichuki and H. Oyieke. *11^{th} World Lakes Conference Nairobi, Proceedings* 2:379 - 383.

Bagalwa, M. 2006. The impact of land use on water quality of the river Lwiro, Democratic Republic of Congo, Central Africa. *African Journal of Aquatic Science* 31(1):137 - 143.

Bootsma, H., Mwita, J., Mwichande, B., Hecky, R.E., Kihedu, J. and Mwambungu, J. 1999. The atmospheric deposition of nutrients on Lake Malawi/Nyassa. pp. 85-111. In: Water Quality Report. Bootsma, H.A. and Hecky, R.E. (Eds.). Lake Malawi/Nyasa Biodiversity Conservation Project, Southern Africa Development Community/ Global Environmental Facility.

Cohen, A.S., Bills, R., Cocquyt, C.Z. and Caljon, A.G. 1993. Impact of Sediment Pollution on Biodiversity in Lake Tanganyika. *Conservation Biology* 7 (3):667-677.

Hecky, R.E., Bootsma, H.A.and Odada, E. 2006. African Lake Management Initiatives: The Global Connection. *Lakes and Reservoirs: Research and Management* 11:203-213.

Irvine, K., Dohoue, I., Wemaere, A., Styles, D. and Hobbs, W. 2003. Connecting land use with water quality: Sources, sinks and time boms. Diffuse Pollution conference, Dublin. Water resources management. pp. 56 - 60.

Johnes, P.J. 1996. Evaluation and management of the impact of land use change on the nitrogen and phosphorus load delivered to surface waters: the export coefficient modeling approach. *Journal of Hydrology* 183:323-349.

Majaliwa, J.G.M., Twongyirwe, R., Nyenje., Oluka, M., Ongom, B., Sirike, J., Mfitumukiza, D., Azanga, E., Natumanya, R., Mwerera, R. and Barasa, B. 2010. The effect of land cover change on soil properties around Kibale National Park in SouthWestern Uganda.

Tenywa, M.M., Tukahirwa, J.B., Bruchara R., Adekunle A. A., Mugabe J., Wanjiku C., Mutabazi S., Fungo B., Kashja N. I. M., Pali P., Mapatano S., Ngaboyisonga C., Farrow A., Njuki J. and Abenakyo, A. 2011. Agricultural innovation platform as a tool for development oriented research: Lessons and challenges in the formation and operationalisation. *Learning Publics Journal of Agriculture and Environmental Studies* 2 (1):117-146.