Research Application Summary

Impact of land use and climate change on stream flow, sediment and pollution dynamics in Kagera river watershed

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Abstract

Kagera River is one of the most important incoming rivers to Lake Victoria with an annual inflow of about 7.5 km^3 into the Lake and is also important to the River Nile which is the single outlet of Lake Victoria. The Kagera River is therefore important for ecosystem health and human wellbeing in the Lake Victoria Basin. However, the Kagera River Basin is facing increased degradation as a result of rapid population growth, agricultural and livestock intensification characterized by unsustainable land use and management practices, which are threatening the basin's freshwater resource base, and associated ecosystem services for both upstream and downstream users. Climate change and variability exacerbates these threats. This study will assess the impact of land use change and climate change on stream flow, sediment and pollution dynamics in the Kagera River Watershed; and the likely land use policy interventions necessary to contribute to the sustainable use and management of the basin's natural resources.

Key words: Fresh water resources, Kagera river watershed, land use

Résumé

La rivière Kagera est l'une des rivières les plus importantes entrant dans le lac Victoria avec un apport annuel d'environ 7,5 km^3 dans le lac, et elle est également important au fleuve Nil qui est la seule sortie du lac Victoria. La rivière Kagera est donc importante pour la santé des écosystèmes et le bien-être humain dans le bassin du lac Victoria. Cependant, le bassin de la rivière Kagera est confronté à une augmentation de la dégradation en raison de la croissance rapide de la population, de l'intensification de l'agriculture et de l'élevage, caractérisée par l'utilisation non durable des terres et les pratiques de gestion, qui menacent les ressources de l'eau douce du bassin et des services d'écosystème associés pour les utilisateurs en amont

et en aval . Le changement climatique et la variabilité accentuent ces menaces. Cette étude vise à évaluer l'impact du changement d'utilisation des terres et le changement climatique sur le débit, les sédiments et la dynamique de la pollution dans le bassin versant de la rivière Kagera, et les interventions susceptibles de politique d'utilisation des terres nécessaires pour contribuer à l'utilisation durable et à la gestion des ressources naturelles du bassin.

Mots clés: les ressources en eau douce, Le bassin versant de la rivière Kagera, l'utilisation des terres

Background

Land and water are the backbone of agricultural and other forms of production and are important especially in the Kagera River Watershed where livelihoods and the economies of riparian countries depend on agriculture. The watershed is one of the most important incoming rivers to Lake Victoria with an annual inflow of about 7.5 km^3 into the Lake, to the River Nile (Haguma, 2007), and for ecosystem health and human wellbeing. However, Kagera River Basin is facing increased degradation due to rapid population growth, agricultural and livestock intensification characterized by unsustainable land use and management practices, which are threatening the basin's freshwater resource base, and associated ecosystem services. Climate variability and change exacerbates these threats (Bates *et al*., 2008). Addressing this challenge requires long-term planning and management to build resilience of both ecosystems and the people. This requires insights into how the future land use, climate and corresponding impacts on water resource may unfold. Studies have been done in the basin to understand land use and hydrological impacts in the Kagera river watershed such as that by Haguma (2007) but no information has been generated on plausible land use scenarios, and downscaled climate change data to give insights to guide or stimulate long-term planning and management. There appear to be no documented study that combines scientific hydrological studies and generation of plausible policy actions in the basin. The current study will assess the impact of land use and climate change on stream flow, sediment and pollution dynamics in the Kagera River Watershed; and the likely land use policy interventions necessary to contribute to the sustainable use and management of the basin's natural resources.

Study Description

The Kegera River Basin (watershed) falls in the boundaries of Burundi, Rwanda, Tanzania and Uganda, countries in East

Africa. It covers a surface area of 59 700 km^2 and forms part of the Lake Victoria Basin into which the watershade discharges up to 7.5 km^3 of water per year which is almost one fourth of the inflow into Lake Victoria. Land use in the basin includes a range of diverse production systems that can be aggregated as extensive and intensive livestock systems; cropping; and mixed farming systems that include agroforestry. In 2006, the basin had a population of 16.5 million who were mainly rural and depended on farming as major source of livelihood.

In this study socio-economic and biophysical data will be required for scenario development and ArcSWAT model construction for simulation of hydrological responses. These will include: land use cover maps for the years 1980, 1990, 2000 and 2010 over the basin obtained by classification of Landsat Thematic Mapper (TM) sensor imagery by applying GIS techniques (Mango *et al*., 2011), supported by field visits and GPS ground referencing; climate data, meteorological data, and downscaled climate change projections (Nandozi *et al*., 2010); river discharge data from country water institutions; population and economic data (GDP) from FAOSTAT data base; soil data from the Soil Terrain Database of East Africa (SOTER); policy documents from relevant country ministries; and water quality and sediment data by sediment and water sampling and analysis for sediment loading, presence of pesticides and agricultural chemicals, total nitrogen, total phosphorus, and pH according to standard methods (APHA, 2005).

Development of future land use scenarios involve interpreting the Intergovernmental Panel on Climate Change (IPCC)'s special report on emission scenarios (SRES) four marker storylines (A1FI, A2, B1 and B2) of Nakic´enovic´ *et al*., 2000 for the Kagera River Basin in a three stage process described by Ewert *et al.* (2005), Rounsevel *et al.* (2005), Rounsevell *et al.* (2006), Verburg *et al.* (2008) and Sohl *et al*. (2012). This involves making a quantitative assessment for each land use total area requirement as a function of change in the land use drivers for each SRES marker scenario; and applying spatial allocation rules to allocate each land use in each scenario across the basin (Rounsevell *et al.*, 2006). The major land use in East Africa which includes agricultural, urban, forest and conservation areas (parks, games and reserves) will be used

while demographic and GDP trends will be considered as the socioeconomic indicators.

Impacts of external factors such as demand for land use goods (agricultural and forest products) that result from the outside of the basin usage will be determined by applying the IMAGE 2.4 model for each of the scenarios (Rounsevell *et al*., 2005 and 2006).

Assessment of urban land use by urban demand estimation will be calculated using an empirical-statistical model with population and GDP as the independent variables (Rounsevell *et al*., 2006; Reginster and Rounsevell, 2006). Assessment of agricultural land use for crop land and grassland will be done by considering drivers of agricultural land use change and estimated by applying a simple supply – demand model for agricultural goods in the basin (countries); and considering the effect of changes in temperature and precipitation (climate change); effect of changes in temperature and precipitation (climate change); effects of increasing atmospheric carbon dioxide concentration; and effect of technology development. Forest land use and land cover scenarios will developed from interpreted SRES storylines as described by Kankaanpaa and Carter (2004). Competition between the different land uses is also addressed in the scenario construction process using a simple land use competition hierarchy.

Experts will be consulted by holding two workshops with at least 20 experts in each basin country (Burundi, Rwanda, Tanzania and Uganda), the first workshop for SRES interpretation and the second for verification of spatial allocation of quantified areas for each of the land uses and scenarios. Interviews will also be undertaken with 20 stakeholders, individuals or organizations working in and having experience in these fields in each country. This exercise will generate a set of drivers, qualitative interpretation, and spatial allocation rules of land use change that are plausible for each SRES marker scenario.

After all data collection and preparation of historical land use maps for the years 1980, 1990, 2000 and 2010 as well as projected land use scenarios for the four SRES marker storylines for 2020 and 2050, simulation of corresponding stream flow, sediment loading and nonpoint pollution will be undertaken using

ArcSWAT, a river basin or watershed scale model, as described by Wincell *et al*. (2010).

Nine focus group discussions will be held do discuss possible policy implications of the land use scenarios and corresponding hydrological impacts. Two discussions will be held in each of the four basin countries, one with members of a selected community and another with the technocrats and decision makers who will be involved in scenario construction. The ninth discussion will be held with technocrats at basin level. The technocrats will be selected based on their expertise in relevant areas such agriculture, land use, and urban development.

Outputs of this study will include future land use and climate scenarios in the basin and corresponding hydrological response; and policy interventions to prevent possible events and enhance if positive, the occurrence of such plausible scenarios. The outcome is expected to stimulate long term anticipatory land use and water resource planning and management that build resilience of ecosystems and communities.

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References

APHA. 2005. Standard Methods for the Examination of Water and Wastewater. WashingtonD.C.

Bates, B.C., Kundzewicz, Z.W., Wu, S. and Palutikof, J.P. (Eds.). 2008. Climate change and water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva. 210pp.

Ewert, F., Rounsevell, M.D.A., Reginster, I., Metzger, M. and Leemans, R. 2005. Future scenarios of European agricultural land use. I. Estimating changes in crop productivity. *Agriculture, Ecosystems and Environment* 107:101–116.

Haguma, D. 2007. Development of a hydrologic model of Kagera River basin using remote sensing data. MSc Thesis WSE-HI.07-01.

IPCC. 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on

Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (Eds.)]. IPCC, Geneva, Switzerland, 104 pp.

Kankaanpa¨a¨, S. and Carter, T.R. 2004. Construction of European forest land use scenarios for the 21st century. In: The Finnish Environment 707, Finnish Environment Institute, Helsinki. 57 pp.

Mango, L.M., Melesse, A.M., McClain M.E., Gann, D. and Setegn, S.G. 2011. Land use and climate change impacts on the hydrology of the upper Mara River Basin, Kenya: results of a modeling study to support better resource management. *Hydrol. Earth Syst. Sci.* 15:2245–2258.

Nakicenovic,N., Alcamo, J., Davis, G.,De Vries, B., Fenhann, J.,Gaffin, S., Gregory, K., Gru¨ bler, A., Jung, T.Y., Kram, T., La Rovere, E.L., Michaelis, L., Mori, S., Morita, T., Pepper, W., Pitcher, H., Price, L., Riahi, K., Roerhl, A., Rogner, H.-H., Sankovski, A., Schlesinger, M., Shukla, P., Smith, S., Swart, R., Van Rooijen, S., Victor, N. and Dadi, Z. 2000. Special Report on Emission Scenarios. Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Cambridge, UK.

Nandozi, C., Komutunga, E., Majaliwa, J.G.M., Aribo, L. and Omondi, P. 2010. Assessment of climate change scenarios and variability in Uganda. *Proceedings of the Second RUFORUM Biennial Meeting 20 - 24 September 2010, Entebbe, Uganda.* pp. 441 - 444.

Reginster, I. and Rounsevell, M. 2006. Scenarios of future urban land use in Europe. *Environment and Planning B: Planning and Design* 33(4):619 - 636

Rounsevell, M.D.A., Ewert, F., Reginster, I., Leemans, R. and Carter, T.R. 2005. Future scenarios of European agricultural land use. II. Projecting changes in cropland and grassland. *Agriculture, Ecosystems and Environment* 107:117 - 135.

Winchell, M., Srinivasan, R., Di Luzio, M. and Arnold, D.J. 2010. ArcSWAT Interface for SWAT2009 user's guide.