Research Application Summary

Post doc experience on unravelling agro ecological and climatic approaches to understanding restoration of watersheds

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Abstract

Watershed health is key to attainment of sustainable development goals in East and Central Africa. However, their rate of degradation is increasingly alarming in these regions due to land-use/cover changes and poor management. On the other hand, several studies have demonstrated that climate change and variability is setting in and is likely to induce a web of devastating effects if no restoration actions are put in place. Watershed restoration actions will require accurate diagnosis of partial contributions of land-use/cover changes and climate change and variability on watershed health, but also identifying best restoration practices to be promoted in these regions in order to achieve the Sustainable Development Goals (SDGs). This paper describes experiences of a Postdoctoral Fellow attached to Makerere University in Kampala as the host institution in the College of Agricultural Sciences for mentorship, three (3) PhD students under the RUFORUM Graduate Teaching Assistantship (GTA) and the Intra African Mobility project plus four (4) Master students. The Post doc Fellow mentored students in research and publishing. The Fellowship attracted a US$60,000 research grant for a time period of 22 months and provided opportunity for multi-disciplinary research, being mentored by senior academicians, being linked to other Fellows across Africa, and gaining experience in mentoring upcoming scientists.

Key words: Climate change, central and eastern Africa, land use management, Makerere University, mentoring, postdoctoral fellowship

Résumé

La stabilité des bassins versants est essentielle à la réalisation des objectifs de développement durable en Afrique orientale et centrale. Toutefois, leur degré de dégradation est de plus en plus alarmant dans ces régions du fait du changement et mauvaise gestion des modes d'utilisation des terres / couvert végétal. D'un autre côté, plusieurs études ont montré que le changement et la variabilité climatiques sont susceptibles d'induire des effets dévastateurs si aucune action de restauration n'est mise en place. Les actions de restauration des bassins versants nécessitent un diagnostic précis sur les contributions relatives des changements des fores d'utilisation des terres et du changement et variabilité climatique, mais également l'identification des meilleures pratiques à promouvoir dans ces régions. Cet article décrit les expériences d'une bénéficiaire de bourse postdoctorale, à l'Université de Makerere à Kampala, de trois (3) doctorants sous le Programme d'Assistanat de RUFORUM et le Projet de Mobilité Intra Africaine, et de quatre (4) Étudiants de Master. La bénéficiaire a encadré des étudiants pour les recherches et publications.

La bourse a attiré une subvention de recherche de 60000 USD pour une période de 22 mois et a permis de mener des recherches multidisciplinaires, d'être encadrée par des académiciens seniors, d'être liée à d'autres boursiers à travers l'Afrique et d'acquérir une expérience dans le mentorat des scientifiques émergents.

Mot clé: Changement climatique, Afrique centrale et orientale, Gestion de l'utilisation des terres, Université Makerere, mentorat, bourse postdoctorale

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Introduction

Watershed are recognized as the main planning units for agricultural, environmental and socio-economic research and development. They are important sources of food, fresh water and raw materials such as poles, herbs and timber for both domestic and industrial use. Their best management will certainly contribute to attaining about half of Sustainable Development Goals (SDGs). However, it has been observed that their rate of degradation is escalating worldwide (Ceci, 2013; Kakuru *et al.,* 2013) and particularly in central and eastern Africa. Watershed degradation manifests in form of water quantity and quality reduction. Globally, it is estimated that by 2025, about 1.8 billion people, a quarter of these in sub Saharan Africa will experience absolute water scarcity due to watershed degradation (Habtamu, 2011; Ceci, 2013). Several surface water in central and Eastern Africa have experienced water level reduction and tremendous decline in water quality. The poor status of the watersheds in these regions is attributed to land-use/cover changes, climate change and variabilities, lack of or poor implementation of existing policies and regulations, and limited information on which meaningful policy and management plans can be based.

Various scholars have observed reduction in forest and wetland ecosystems in central and eastern Africa (Barasa, 2011; Egeru, 2014; Bagalwa *et al.,* 2017). These changes are driven by demographic pressure and their associated demand on food and energy. Studies in various parts of the two regions indicated temperature increase with no significant change in rainfall (Majaliwa *et al.,* 2017). These changes in temperature coupled with poor land management and lack of or inadequate policy and regulation implementation accelerate watershed degradation in both regions. Several rivers become seasonal, water level reduced, and there is proliferation of aquatic plant with negative consequences on the biodiversity, etc.

Statement of the research problem. The increased degradation of watersheds in Central and Eastern Africa regions has culminated into loss of livelihood assets for the various communities relying on the watershed resources, increased purification cost for water distribution institutions, and limited electricity production, among other. Subsequently this has affected negatively community development in various localities of both regions. Understanding the contribution of the aforementioned drivers change and the identification of best management practices capable of restoring and maintaining the ecosystem services within the watershed under projected climatic conditions is key in the development of successful watershed restoration plan. This necessitate training of skilled and holistic professionals able to generate adequate management and restoration plans for degraded and trans- boundary watershed. To address the above problem, there is need to develop appropriate research capacity for development of technologies and innovations for

ecosystem resilience. A key strategy is to enhance postgraduate training where students and their faculty advisers undertake research to address the gap. To contribute to this effort, PhD and MSc. students worked on related topics together with faculty staff at Makerere to address some of the research issues. This provided opportunity for the newly graduated Doctoral person to receive academic guidance from a senior university academic to strengthen her research skills. Working with the team of graduate students helped the Fellow develop team work spirit and skills to supervise young scholars.

The specific objectives of the Postdoctoral Fellowship were to: strengthen research skills of the Post- Doctoral research Fellow; strengthen the capacity and skills of the Doctoral Fellow to provide academic guidance and mentoring to postgraduate students; and to generate research results to guide interventions and to generate publications and information to strengthen regional watershed management.

Design of the post-doctoral programme. The Fellow is a lecturer in Makerere University at the College of Agricultural and Environmental Sciences. She worked under the guidance of a senior academic rof. Majaliwa Mwanjalolo as the main mentor, but also with other academics working in the area of watershed management at Makerere. Professor Majaliwa is a Watershed Management Specialist. The Fellow worked under an Intra African Mobility research and training project dealing with issues of ecosystem resilience. The Project involved training of four (4) MSc students. There were 3 PhD students that studied related topics. Thus Makerere served as the host institution, and the Fellow participated in research activities linked to the graduate students' theses research.

Under the guidance of the Mentor and other faculty academics, the Fellow led a team of 7 researchers (4 MSc and 3 PhD) to pursue thesis research in the broad area of watershed management. In this process the Fellow provided academic guidance to the graduate students, worked with them to deliver seminars and conference presentations and also publish papers. Further, with the guidance and support of the mentor and other academic staff, the Fellow developed a proposal for funding research and other training initiatives. Additionally, the Fellow participated in networking activities such as the Annual General Meeting of RUFORUM that was held at University of Cape Coat in Ghana in December 2019 and the Annual Forum for Science Granting Councils Initiative in Sub Saharan Africa/ Global Research Council Regional meeting for Africa that took place at Dar es Salaam in November 2019. These convenings helped the Fellow to be linked to other Fellows across Africa and also leading scientists in the continent and globally.

As part of supporting RUFORUM thrusts, the Mentor and the Fellow worked with PhD research students under the RUFORUM Graduate Teaching Assistantship program. Additionally there was a deliberate effort to include 2 female students, as part of contributing to RUFORUM thrust to increase the pool of women scientists as spelt out in the RUFORUM Vision 2030 Strategy.

Methodology and design of the research study

This action trained 3 PhD and 4 MSc students on climate and land-use/cover change projections and their associated effects on watershed stability and biodiversity conservation. All the PhD studies were conducted in Lake Kivu basin in DR Congo while the four master students carried

out their research in Uganda in the respective degradation hot spot areas. All the students were registered with the College of Agricultural and Environmental Sciences of Makerere University in various departments. Each of the studies was conducted over a 2-year period. The three PhD students were Graduate Training Assistance who benefited from RUFORUM grant and needed only research money to complete their studies. On the other hand, all the master students had completed their coursework and were set for field data collection but did not have any research funds. The research funds were provided through the Fellowship research grant

Complementarity of the seven (7) studies. The studies were on pollution and restoration action as detailed: PhD study 1 was on air pollution, PhD study 2 on soil pollution and PhD study 3 on best practices. The four MSc. studies looked at restoration action and best practices of watersheds.

Student 1, Ph.D. Azanga Ekaka Oscar studied Climate change and land-use/cover impacts on water balance in a multi-dammed river system. This student focused on future change in climate, projected trends in land-use/cover, the effect of projected climate and land-use/cover on water balance and determined the best land management options for improved water flow in Lake Kivu basin. A multi-phased approach combining experiments and modeling was used to establish the relationship between climate change and land use/cover and the hydrology of the dammed river system. Historical weather data were collected and analysed. Temperature and rainfall trends were projected using the NASA R-script for Mid-century (2041-2070) and End-century (2071-2100), for 4.5 and 8.5 Representative Concentration Pathways (RCP). Land use/cover change and trend assessment was analysed using Landsat image analysis and use of trend earth cloud based tool. The future land-use/cover change projection was based on identified driver of change. The projected climate and land-use/cover was used in hydrological model to determine projected contribution of land-use/cover and climate on water balance. An experiment was also conducted in order to determine the best soil and water conservation practices which sustain adequate flow water under changing climate and land-use/cover conditions.

Student 2 PhD Bagalwa Mashimango Jean Jacques focused on major sources of atmospheric deposition of nutrients. The major goal of this activity was to gain understanding of seasonal changes in the sources and pathways of atmospheric nutrient deposition loading into surface waters. Specifically, this action a) determined atmospheric nutrient and major ions deposition under different land uses; b) determined the origin of nutrients (N and C) loading in Lake Kivu via atmospheric deposition, and c) simulated the effect of atmospheric deposition of N and P on the eutrophication rates of water body. Dry and wet atmospheric deposition were analyzed in the four majors land use/cover types namely forest, agricultural, settlement and wetland. Analysis of nutrient (DOC, DIC, TP, SRP, TN, NO_3^-, NH_4^+) was done using colorimetric spectroscopic method. The origin of nutrients (N and C) loading into Lake Kivu via atmospheric deposition was monitored during the study period using stable isotope of N and C. The measurement of the natural abundance ratios of carbon and nitrogen stable isotopes ($^{13}C/^{12}C$ and $^{15}N/^{14}N$) in dry and wet atmospheric deposition was done according to the methods developed by Ngochera and Bootsma (2011). The $^{13}C/^{12}C$ ratios of the resulting CO_2 was determined using a Finnigan MAT Delta+ mass spectrometer in a Dual Inlet system at the Great Lakes Institute at Wisconsin (USA). Isotopic ratios for carbon, reported as $\delta^{13}C$, was calculated as: $\delta^{13}C = (^{13}C/^{12}Csample / ^{13}C/^{12}Cstandard - 1) \cdot 1000$ (‰). The relationship between atmospheric concentration of nitrogen and carbon and wind direction was assessed using meteorological data and seasonal atmospheric nutrient concentration

at the different stations around the lake. The data were analyzed using correlation method as proposed by Monteith *et al.* (2016). In order to mimic the conditions, found in Lake Kivu, surface water was collected below 8 m depth (Soranno *et al.,* 1997) twice the season, and mixed to form a compose sample. The collected water was analyzed for Chlorophyll-a and DOC before experimentation. In addition, water samples exposed to dry and wet (rainwater) deposition were collected at different sites around the catchment and analyzed for TP and TN. These samples were mixed with the composite sample. Chlorophyll-a and DOC were measured after 1, 15 and 30 days (Morana *et al.,* 2015) in the mixed water. Two blanks were prepared for rain water and lake water without mixing respectively.

Student 3 PhD; Mukengere Bagula Espoir worked on water use efficiency under selected soil and water conservation practices and impact assessment of climate change in Ruzizi catchment, Eastern DR Congo. This activity aimed at   increasing our understanding on water use efficiency and enhance the adaptive capacity of farmers in Ruzizi catchment. Specifically it a) evaluated water use efficiency of selected SWC practices along the landscape position, b) determined nutrient and water balance of selected SWC practices along the landscape position, c) evaluated the performance SWC under different Climate change scenarios and RAPs, and d) evaluated the socio economic impacts of climate change on maize producing farms and vulnerability under selected SWC. This study used experimental, survey and modeling approaches. For the experiment three trials were conducted along topo sequence positions with three soil and water conservation practices (Tied Ridges, Zaï and Conventional tillage as the control) as treatments. Data related to crop physiology, maize agronomic parameters and soil and water conservation were collected for the crop model calibration. Runoff plots were added to estimate full water and nutrient balance for the different SWC. The DSSAT-CERES Maize model were tested under different climate change scenario and Global Circulation Models (GCM). The model was calibrated and validated using experimental data and socioeconomic data obtained through survey. A tradeoff Analysis for Multidimensional Impact Assessment was used to estimate the economic and environmental gains of the selected technologies for the different Representative Agriculture Pathways under changing climate condition.

Student 4 MSc, Church Hill Nokrach, assessed briquette market structure in Central Uganda. Specifically he i) characterized briquette supply chain players, ii) examined the level and forms of competition in briquette business, iii) analyzed the extent of product differentiation in briquette market, and iv) determined the factors that influence performance of briquette value chain. A cross sectional survey using mixed method was employed using data collected from 145 respondents purposively and through snow balling. Descriptive analysis was carried out for objective one, objective two and three regression models were run to ascertain the forms, levels and extent of product differentiation in the briquette market; Ordinary Least Square determined factors that influenced performance.

Student 5 MSc, Wanican Lilian Angala, evaluated land for agricultural land use at household level in Moro District of Northern Uganda. She i) assessed the relationship between agricultural production and land ownership, ii) found out how land is acquired by farmers and the associated impact on the level of production, iii) assessed the physical suitability of district soils to the existing cultivated crops, and iv) established the level of indigenous knowledge in land evaluation and use planning. The hypothesis tested was that that there was no significant difference between

the levels of production and land characteristics. A Cross sectional research design using mixed methods was adopted for the study. Content analysis was used to generate themes used for qualitative data and descriptive analysis and chi square for quantitative data.

Student 6 MSc, Niwamanya Rogers M, looked at effectiveness of community conserved areas in biodiversity conservation in Kacheera wetland in Western Uganda. This student specifically i) compared the biological attributes of community managed ecosystem with an open access regime; ii) assessed stakeholder perception and two regimes towards biodiversity conservation, and iii) established how cultural attachment to natural resource contributed to biodiversity conservation. The study adopted a Cross sectional research design using mixed methods. Qualitative data were analysed through content analysis to generate themes and quantitative data through Chi test of independence for each regime for comparison purposes. Biological targets were on Perceptions, Physio chemical parameters of water pH, Electro conductivity, Dissolved oxygen TDS, nitrites, nitrates ammonia, phosphorous and phosphates within the wet land, and vegetation species. On site measurements of pH, Electrical conductivity, Dissolved oxygen, and TDS were done using a potable multi probe robust model PHEP 5 TESTR by HANNA. Nitrites, nitrates, ammonia and phosphorus and phosphates were determined using a potable field Multi parameter Aquaculture Photometer of the HANAA make. Stake holder perceptions and attachment to cultural values towards biodiversity conservation within the two agroecologies were analyzed using proportions of responses, thematic and Content analysis

Student 7 MSc, Kukunda Loyce, analysed the projected flood trends in Manafwa catchment and evaluated existing land management practices on flood mitigation in river Manafwa in Eastern Uganda. She specifically, i) Projected climate induced risk potential of flooding in Manafwa catchment, ii) Mapped the flooded plains, and iii) Identified best management practices to curb the flood risk. HEC-RAS integrated in ArcGIS was used in projection of future flood risks. The model was calibrated and validated using historical information and flood reconstructed simulations. A survey was conducted to identify existing and sustainable land management practices being promoted by the Uganda Ministry of Agriculture, Animal Industry and Fisheries. The efficiency of the different practices was tested in a flood model.

Quality of research design and ethical consideration. The Fellow ensured that students used proper research designs, data collection and data analysis tools. These include construct validity, internal validity, external validity and reliability tests. Validity ensures the measurements of precision, accuracy and relevance of the study (Amin, 2004; Yin, 2006). By employing the validity measures, the study findings become trustworthy. Ethical considerations was given attention in terms of confidentiality of information and not using humans as specimen for data collection.

Overview of the Post-Doctoral Fellowship Programme: RUFORUM (Regional Universities Forum for Capacity Building in Agriculture, see www.ruforum.org for more details) made a 2-year post-doctoral Fellowship call targeting Carnegie supported doctoral alumni between 2012- 2017 in 35 African countries. This was to strengthen postgraduate training and academic mobility in Africa. The Fellowship was meant to increase and ensure high retention of graduates in African universities and research institutions to meet the growing demand for higher education and research by creating knowledge and prosperity in the continent. This was through facilitating recent PhD graduates in ways that would improve their research, leadership and mentoring

skills. The forming of a research team assisted in strengthening supervision skills of the Post doc Fellow, Masters and PhD students, with a spill over to undergraduate students. The research team contributed to building a critical mass of young scientists in Africa with a strong network to reinforce sharing of knowledge and approaches. The research will make great contributions to scholarship for the Post doc Fellow, PhD and master students. The Fellow was also supported to contribute to more publications and write research grants proposals which contributed to improving ranking of Makerere University.

Mentorship Plan. The mentorship plan integrated postgraduate students as part of the research team, supported them to finalise their dissertations within the Fellowship stipulated time and met the criteria for the award of degrees to them. This was done through monthly progress checks against set targets and updating the senior mentor regularly. Quarterly meetings were held by the team and chaired by the team of mentors, a six month progress and a completion report to RUFORUM at the end of the Fellowship were submitted. This encouraged mentorship and training for all by more senior scientists. The Post doc Fellow took only a week of lectures in order to provide apple time to mentor the seven students. There were opportunities of linking other Fellows as well as participating in the RUFORUM Biennial (October 2018 in Nairobi, Kenya) and Annual conference (Cape Coast Ghana, December 2019).

Sharing experiences. The Fellow developed the ability to handle pressure and understand the various studies, an opportunity not only to increase on the knowledge base but also handle multidisciplinary studies and the complexities this comes with. The Fellow also interacted with Faculty academicians and graduate and undergraduate students in the College of Agriculture and Environmental Sciences, and visited the students' research sites where she interacted with other actors. Importantly, the periodic reviews with the students under the Fellow's guidance helped build her student supervision skills while it allowed critical reviews and feedback by the students and academic staff. The approach also showed that strategic use of limited funding, as provided under this Fellowship, can help a number of students pursue their research studies. The Fellow and Mentees therefore applaud the design of this Fellowship programme.

Manuscripts for publication
The following are the titles of the manuscripts under development for targeted journals

1. Atmospheric deposition of nutrients on freshwater: a review of literature. *Journal of Environmental Protection (JEP)*
2. Impact of land use/cover activities and atmospheric nutrients deposition a round Lake Kivu, Democratic Republic of Congo. *The Journal International Academy of Science, Engineering And Technology (IASET)*
3. Major soluble ions in wet and dry atmospheric deposition around Lake Kivu, DR Congo side. *Journal of Environmental Science and Pollution Research*
4. Relationship between atmospheric deposition of nutrient (N and P) concentration and wind direction in Lake Kivu watershed, DR Congo side. *Scholars Academic Journal of Biosciences (SAJB)*
5. Simulation of the effect of atmospheric deposition of N and P on the eutrophication rates of Lake Kivu, DRC side. *Journal of Water Research*
6. Water use efficiency under selected soil and water conservation practices along the toposequence

gradient in Ruzizi watershed, Eastern DR Congo. *Journal of Agriculture Water Management*

7. Water and nutrient balance under selected soil and water conservation practices in Ruzizi catchment, Eastern DR Congo. *Journal of International Soil and Water Conservation Research*

8. Soil water conservation performance in different climates zones in rain fed Sub-Saharan Africa Agriculture. *Journal of International Soil and Water Conservation Research*

9. Dynamics of Land Use / Cover in the River Ruzizi Basin. *Journal of Environmental Planning and Management*

10. Future Climate in the River Ruzizi Basin. Climatic Change, Springer

11. Effect of land use/cover and climate change on the water balance in River Ruzizi basin

12. Best land management for sustainable for hydropower generation on River Ruzizi

13. The Structure and Conduct of Briquette Market in Greater Kampala. *African Journal of Environmental protection*

14. Profitability on the briquette Business: a Case of Greater Kampala. *AJRD*

15. Are Briquette Actors Making Profit? A case of Greater Kampala. *AJRD*

Acknowledgement

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