

Building Capacity for Climate Change Mitigation and Adaptation Through Mainstreaming Climate Change in Curricula of Tertiary Training Institutions in Africa

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Abstract Climate variability and change, which intensified since 1970s, are threatening natural resources and livelihoods in Sub-Saharan Africa where people depend on climate sensitive natural resources, such as agriculture and fisheries, but have limited capacity to adapt. Increasing human and institutional capacity to address threats posed by climate change to natural resources and livelihoods requires building capacity to generate and disseminate information and knowledge on climate change, its impacts, adaptation and mitigation through research, education and raising awareness by tertiary training institutions. Most tertiary training institutions in Africa have curricula covering basic and applied natural resources management but most of them do not include climate change. This paper presents a training curriculum and manual that was developed to fill this gap. The purpose of

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the paper is to provide in-depth information on how Climate Change can be integrated into the fisheries and aquaculture curricula of tertiary training institutions. It also provides students, scientists, practitioners, and policy makers with an understanding of key concepts and approaches to climate change mitigation measures, adaptation strategies, and policies. The aim is to mainstream climate change in fisheries training. The specific objectives are to facilitate introduction of climate change in fisheries training in Uganda that can be developed further and adopted by other countries in Africa and elsewhere; Equip students with scientific and technical capacity to anticipate and evaluate changes in climate and its influence, communicate information to stakeholders, design, and test adaptation strategies and mitigation measures; and Increase human resource capacity to address climate change issues through reviewing and strengthening of the national education system. The curriculum consists of seven modules covering: Major threats to natural resources; Introduction to climate change; Implications of climate change on aquatic productivity processes and fisheries; Implications of climate change on aquaculture; Livelihoods, impacts, adaptation and mitigation; Aquatic ecosystem modeling in relation to climate change; Principles, policies, regulations and institutions required to address impacts of climate change. The modules will be delivered through lectures, discussions, case studies and field visits. It is recommended that the curriculum and manual be incorporated into training programs of tertiary training institutions to build the capacity required to address climate change challenges particularly for fisheries in Africa.

Keywords Climate change • Adaptation • Mitigation • Capacity building • Fisheries resources • Livelihoods • Tertiary institutions • Uganda

1 Introduction

Climate variability and change are increasingly becoming a major environmental, social and economic challenge contributing to poverty and food insecurity through increased temperature and extreme events such as floods and drought. Africa is among the most vulnerable continents due to its high poverty levels and dependence on climate sensitive rain-fed agriculture and natural resources comprising of livestock, forestry and fisheries (IPCC 2007). About 240 million people in Sub-Saharan Africa are poor and food insecure and 70–80% of the population of the region depends on the vulnerable agriculture and natural resources (FAO 2010). Unless action is taken to curtail impacts of the increasing variability and change in climate, Africa is not likely to attain the Sustainable Development Goals, particularly those that aim at ending poverty; ending hunger, achieving food security and improved nutrition and promoting sustainable agriculture; combating climate change and its impacts; and conserving and sustainably using the oceans, seas and marine resources for sustainable development.

Addressing impacts of climate variability and change in developing countries has concentrated on crops, livestock and forestry and less on fisheries despite the high economic and nutritional value of fish. Fisheries provide about 15% per capita animal protein for 7.3 billion people globally, employ 10–12% of the world's population and generate about \$125 billion in exports (FAO 2012). Fisheries are also important at national level in different countries. For instance, in Uganda, fisheries contribute 2.5% to national GDP and 12.5% to agricultural GDP, employ about 1.2 million people, provide 50% of animal protein to the population, and fish is the most important non-traditional export commodity (MAAIF 2012). In addition, the highest human and livestock populations live in proximity to aquatic systems.

There is growing evidence that climate variability and change are either acting independently or adding to the other stressors to alter temperature, rainfall, water levels, water balance, aquatic productivity processes, life history and biological characteristics of fishes, diversity of aquatic organisms, and fish yield, which ultimately affect livelihoods (Sumaila et al. 2011; Cheung et al. 2013; Ogutu-Ohwayo et al. 2016). Ogutu-Ohwayo et al. (2016) discuss extensively how climate variability and change is influencing fisheries resources and livelihoods using experiences from different aquatic systems across Africa. Based on evidence presented in the paper, it is clear that climate variability and change has consequences on fisheries such as shifts in fish composition, and fish yield. For example, the contribution of stocks of *Rastrineobola argentea*, locally known as Daga/Omena/Mukene, in lakes Kyoga and Victoria and related small pelagic cyprinids in Lake Albert, Uganda, have increased to 40–80% of the fish yield over the period when climate variability and change intensified. This is in line with the prediction by FAO (2010) that climate change will shift fisheries to smaller, faster growing, and pelagic opportunistic species. In Lake Wamala (Uganda), an environmental change hot spot due to climate related conditions (UNEP 2009), the composition and life history of fishes have changed with rainfall and water level (Natugonza et al. 2015; NaFIRRI 2013). Fishers around Lake Wamala, like others around African lakes, have adapted by diversifying to other livelihoods such as crop agriculture among others (Musinguzi et al. 2016; Ogutu-Ohwayo et al. 2016). There is therefore need to build capacity, generate knowledge, develop adaptation and mitigation measures, develop and implement policies and increase awareness to address the impacts of climate variability and change on inland aquatic ecosystems, fisheries and livelihoods.

Success in addressing the influence of climate variability and change on inland aquatic ecosystems and livelihoods will require local academic and research institutions with capacity to anticipate and evaluate changes in climate, communicate information to policy makers and stakeholders, and design, test and implement appropriate adaptation strategies and mitigation measures, which is however inadequate in most institutions in Africa.

1.1 The Role of Tertiary Training Institutions in Building Capacity for Climate Change Mitigation and Adaptation

A key goal of tertiary training institutions has been to provide solutions to global development challenges (Bloom et al. 2005). Tertiary training institutions play a critical role in helping society to adapt to impacts of climate variability and change by creating awareness through research and training focusing on climate change impacts, adaptation strategies and mitigation measures. They can therefore act as role models and serve as 'hubs' in their local communities for creating, testing, and disseminating knowledge about climate change impacts, mitigation and adaptation strategies. However, these roles can only be fulfilled if climate change is integrated in the curricula of the tertiary training institutions. There is therefore need for mainstreaming climate change into the curricula of tertiary education institutions as climate change is becoming a challenge to Africa's development efforts that depend on climate sensitive sectors for livelihoods (Allison et al. 2009). Indeed, the incorporation of climate change in all aspects of education and training is recommended by current national, regional and international policies because the challenge posed by the increasing variability and change in climate is now recognized at all the levels. Efforts should be put to ensure that climate change is comprehensively incorporated into curricula of tertiary institutions in Africa. Currently, most tertiary training institutions with fisheries curricula for training professionals to conduct basic and applied research in capture fisheries and aquaculture and manage fisheries resources have limited or no coverage of climate change. As a result, students and graduates of tertiary institutions will be well-versed with the challenges posed by climate change to be better prepared to advise the communities on appropriate climate change mitigation and adaptation.

It was against this background that the Department of Zoology, Entomology and Fisheries Sciences, College of Natural Sciences, Makerere University, in collaboration with the National Fisheries Resources Research Institute (NaFIRRI), Uganda, with support from The Rockefeller Foundation, developed this training curriculum and manual as a contribution to building capacity in addressing climate change issues in inland aquatic ecosystems, fisheries and aquaculture.

1.2 The Climate Change Project

The curriculum and training manual was developed as part of a climate change project titled "Equipping Small Scale Fishers and Riparian Communities with Adaptation Strategies to Cope with Impacts of Climate Variability and Change" that was implemented from 2011 to 2014. The purpose of the project was to mainstream climate change in fisheries research on aquatic ecosystems and develop tools that would be applied to address impacts of climate change in fisheries in Uganda, the African Great lakes and elsewhere. The overall objective of the project

was to equip small scale fishers and riparian communities with knowledge, adaptation strategies, mitigation measures and policy guidelines to cope with impacts of climate variability and change to increase their resilient to sustain livelihoods. The specific objectives were to: (i) Improve knowledge systems; (ii) Provide policy guidance; (iii) Increase awareness; and (iv) Improve capacity. The objectives were achieved by literature review supplemented with empirical field observations on two satellite lakes (Wamala and Kawi in Uganda) which have manifested changes in the environment, ecological and biological characteristics of organisms with changes in climate variables. Given the multidisciplinary and multi-sectoral nature of climate change and the fact that climate change interacts with other environmental factors in affecting fisheries resources and livelihoods, holistic understanding of the impacts of climate change on fisheries resources and livelihoods could not be achieved within the scope and time frame of the project that lead to the development of this curriculum and training manual. Moreover, climate change analysis requires time-series data which was not always available or accessible. However, the empirical field observations and literature review upon which this training manual is based provide some start-up for addressing climate variability and change in inland aquatic and riparian ecosystems.

Evidence from literature indicated that changes in climate variables influence riparian and aquatic ecosystems, aquatic productivity processes, composition, distribution, life history and yield of fishes, aquatic weeds, parasites and disease interactions (NaFIRRI 2013; Namboowa 2015; Natugonza et al. 2015) and impacted livelihoods of small scale fishers and riparian communities who were forced to adapt to increase resilience to sustain their livelihoods (Musinguzi et al. 2016). This was supported by field observations which showed that temperatures increased by 0.02–0.03 °C annually since the 1980s and rainfall was above average since 1990s in line with what had been reported for the East African region (NaFIRRI 2013; Natugonza et al. 2015). The composition of fishes changed with the contribution of the African catfish and the lungfish increasing and that of the Nile tilapia decreasing (Natugonza et al. 2015). The changes in variety and quantity of fish affected the livelihoods of fishers with some fishers adapting by switching to the African catfish and the lungfish, diversifying to crops and livestock and irrigating crops during drought. More innovative fishers diversified to high value crops such as pineapples, oranges, tomatoes, cabbages, and livestock and poultry (Musinguzi et al. 2016). It was noted that adjustments to international, regional and national policies on management of environment, water, pollution, biodiversity, fisheries, wetlands, lake shores and river banks, land use, forests, and agriculture are needed to accommodate the impacts of climate change.

1.3 Purpose and Scope

The purpose of this training curriculum and manual is to contribute to building capacity to address climate change issues in inland aquatic systems, fisheries and

aquaculture by initiating the process of introducing climate change in capture fisheries and aquaculture training in Uganda, although it can be developed further and adopted by other countries in Africa and elsewhere. This is because the capacity to address climate change challenges in fisheries is still weak or non-existent and there is therefore need to provide manpower that can generate knowledge to address climate change and its effects on resources and livelihoods. Existing efforts in addressing climate change on natural resources have concentrated on forestry, crops and livestock and less on fisheries despite the high economic importance in some countries like Uganda. In addition, fisheries research and training on inland aquatic ecosystems has concentrated on lake productivity processes and threats such as over-exploitation, invasive species, habitat loss and pollution with very little focus on climate change. As a result, there is limited capacity and knowledge on how the riparian and aquatic ecosystems, productivity processes, fisheries and livelihoods are affected by the increasing variability and change in climate to facilitate development of planned adaptation and mitigation strategies. This training curriculum and manual is intended to reverse this trend. The proposed training will complement existing fisheries Certificate, Diploma, Bachelor and Master of Science, and Doctor of Philosophy (PhD) programs in tertiary training institutions in Uganda, Africa and elsewhere.

1.4 Goal and Objectives

The overall goal of the training curriculum and manual is to provide guidelines for mainstreaming climate change issues in fisheries and aquaculture training in tertiary education institutions.

The specific objectives are to:

1. Facilitate introduction of climate change in fisheries and aquaculture training in tertiary education institutions;
2. Equip students with scientific and technical capacity to anticipate and evaluate changes in climate and its influence, design, test and implement adaptation strategies and mitigation measures and communicate information to stakeholders; and
3. Increase human resource capacity to address climate change issues through reviewing and strengthening of the national education system.

1.5 Learning Outcomes

By the end of the course, participants should be able to:

- (i) Explain the fundamentals of climate change science;
- (ii) Articulate the implications of climate change to natural resources and livelihoods of local communities;

- (iii) Provide a rationale for climate change mitigation & adaptation measures and propose actions for the fisheries sector;
- (iv) Present national, regional and international climate change legal, policy and institutional frameworks;
- (v) Communicate climate change issues to stakeholders in the fisheries sector.

1.6 Target Audience

The target audience of this training curriculum and manual includes: Fisheries and aquaculture certificate, diploma, university undergraduate and graduate students. The training curriculum and manual is designed to complement the ongoing fisheries and aquaculture courses through incorporating climate change into the curricular and developing human resource capacity.

2 Course Structure and Content

The manual is organized into seven modules, each consisting of sub-sections covering: Major threats to fisheries resources; Introduction to climate change; Implications of climate change on aquatic productivity processes and fisheries; Implications of climate change on aquaculture; Livelihoods, impacts, adaptation and mitigation; Aquatic ecosystem modeling in relation to climate change;

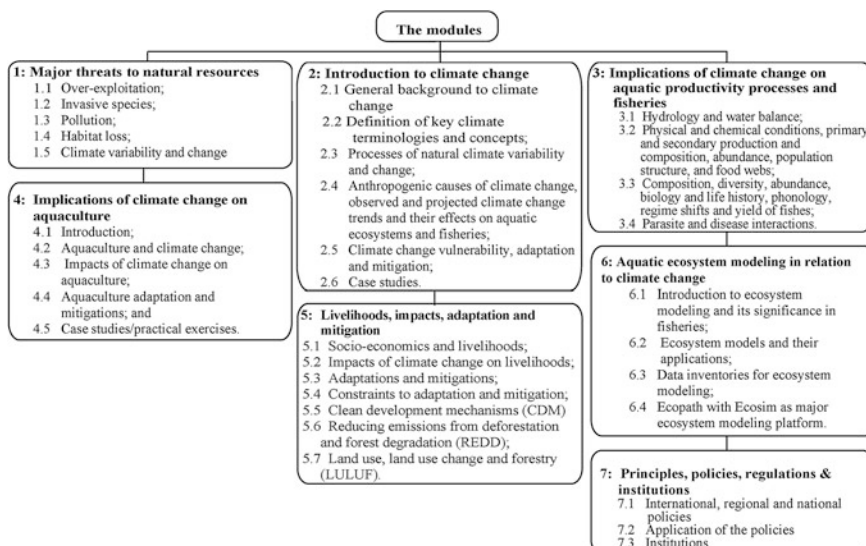


Fig. 1 Description of the modules and subsections of the training curriculum and manual

and Policies for addressing climate change on inland aquatic systems. Descriptions of each module are provided in Fig. 1 and Sect. 3. Each module consists of units to be delivered through lectures, and practical/field excursions in collaboration with research and training institutions in Uganda with mandates relevant to the course including: the Department of Zoology, Entomology and Fisheries Sciences, Makerere University; the National Fisheries Resources Research Institute (NaFIRRI); the Fisheries Training Institute (FTI); the Uganda National Meteorological Authority, the Climate Change Department of the Ministry of Water and Environment; the Directorate of Water Resources Development; the Wetland Division; and institutions dealing with climate change policy.

3 Description of the Modules

3.1 Module 1: Major Threats to Natural Resources

This module describes how different threats influence aquatic ecosystems and fisheries. It examines causes of the threats and how they influence physical and chemical conditions, aquatic and fishery productivity processes, and fish yield and how they may interact with climate change. It then discusses strategies that can be applied to mitigate the influence of the threats and thus help in better management of aquatic ecosystems and fisheries.

3.1.1 Learning Objectives

By the end of this module, participants should be able to: (a) Demonstrate knowledge of the major threats to aquatic ecosystems and fisheries; (b) Show an appreciation of the causes and effects of the threats on physical and chemical conditions, aquatic and fishery productivity processes and livelihoods; (c) Propose strategies that can be applied to reduce the threats; (d) Identify suitable measures for better management of aquatic ecosystems and fisheries.

3.1.2 Lecture Topics

The module starts with an introduction to aquatic ecosystems and their importance (water, transportation, recreation, fisheries etc.); gives an overview of major threats to aquatic systems and fisheries; and provides examples of different threats, their causes and potential impacts. Section 1.1 looks at over-exploitation (unsustainable exploitation of fisheries) including types and causes and control measures. Section 1.2 provides an overview of invasive alien species: definition; major sources of invasive species; their impacts on ecological and ecosystem functioning;

control of invasive species and prevention programmes using the Nile perch and water hyacinth as examples in Uganda. Section 1.3 describes the nature and sources of pollution (microbial, eutrophication, chemical) and management of pollution (legislation and environmental quality monitoring). Section 1.4 presents habitat loss including its causes; examples of habitat degradation such as land use, wetland loss; ecological effects; remediation and control. Section 1.5 introduces climate variability and change as a major threat to aquatic ecosystems and fisheries and its potential interaction with the other threats. The lectures will be complemented with field visits.

3.2 Module 2: Introduction to Climate Change

This module provides an introduction to climate science, its importance and historical development and basic concepts of climate change science such as weather, climate, the greenhouse effect, global warming and natural climate fluctuations. It then defines key climate change terminologies, discusses the main causes and elements of anthropogenic (human caused) climate change, including observed and projected changes in climate at global and regional scales. The module concludes with a discussion of potential impacts of climate change, adaptation and mitigation options for reducing and managing the effects of climate variability and change.

3.2.1 Learning Objectives

By the end of the module, participants should be able to: (a) Explain the basic concepts of climate science and climate change; (b) Define key climate change terminologies; (c) Identify the anthropogenic drivers of climate change (greenhouse effect); (d) Explain observed and projected trends in climate and their impacts on the aquatic ecosystems and fisheries; (e) Explain the concepts of vulnerability, exposure, sensitivity, resiliency, adaptation and mitigation and their importance in preparation for and coping with effects of climate change.

3.2.2 Lecture Topics

Section 2.1 introduces participants to basic climate change concepts such as climate system, climate change, climate variability, vulnerability, sensitivity, adaptation, adaptive capacity, resilience, cryosphere, greenhouse gas emission scenarios, extreme weather events, global warming, green house effect, mitigation, palaeoclimate, etc. Section 2.2 provides definitions of key climate change terminologies and components of the climate system: the atmosphere, ocean, cryosphere, and biosphere; interactions among the components (e.g. earth's energy balance,

surface energy balance, hydrological cycle, atmospheric circulation, ocean circulation). Section 2.3 discusses processes of natural climate variability and change with emphasis on Africa. Section 2.4 presents observed and projected climate change trends and their impacts on the aquatic ecosystems and fisheries. Section 2.5 introduces the concepts of climate change vulnerability, adaptation and mitigation and highlights how to assess vulnerability to climate change as well as highlighting adaptation and coping strategies related to aquatic and riparian ecosystems and fisheries. The section also presents some of the key international, regional and national levels mitigation mechanisms including afforestation, reforestation, promotion of energy efficient systems, improvement of crop production systems, waste management, and promoting Clean Development Mechanisms (CDM). The lectures will be supplemented with practical exercises and case studies.

3.3 Module 3: Implications of Climate Change on Aquatic Productivity Processes and Fisheries

This module examines the influence of climate variability and change on hydrology, water balance, physical and chemical conditions such as transparency, nutrient loading, stratification, circulation dynamics and oxygen levels which drive plankton production, composition, population structure, food-webs, life history characteristics, physiology, composition, distribution, phenology, regime shifts, biological characteristics of fishes, fisheries, fish yield and ultimately livelihoods.

3.3.1 Learning Objectives

By the end of the module, participants should be able to:

(a) Describe the processes through which climate change may affect hydrology, water balance, physical properties of inland aquatic ecosystems, primary and secondary production and composition, population structure, and food-webs; (b) Articulate how abundance, biology and life history and yield of fishes are influenced by climate variability and change; (c) Explain the effects of climate variability and change on the physiology, phenological changes and regime shifts; and d) Explain the effect of climate change on species invasions and disease organisms (parasites and diseases interactions).

3.3.2 Lecture Topics

Section 3.1 examines the effect of climate change on hydrology and water balance (water levels and water budget). Examples will be drawn from small water bodies in Uganda (Lakes Wamala and Kawi) where changes in climate

parameters (i.e., temperature and rainfall) have been reported to influence hydrology and water balance (Natugonza et al. 2016). The section also describes the effects of climate change on physical and chemical conditions such as circulation dynamics, production processes, stratification and mixing, recycling of nutrients, and oxygen circulation; primary production and phytoplankton composition; secondary production (zooplankton) and benthic organisms; composition, diversity, distribution, abundance, population structure and foodwebs. This will be illustrated with case studies from literature in various tropical lakes (e.g., Hecky et al. 2010; O'Reilly et al. 2003; Ogutu-Ohwayo et al. 2016). Evidence from literature will also be used to demonstrate that climate variability and change can operate independently or interact with other factors to modify circulation dynamics, stratification, loading and recycling of nutrients and oxygen in aquatic systems (Hecky et al. 1994, 2010; Lehman et al. 1998; Lorke et al. 2004; Verburg et al. 2003; Vollmer et al. 2005; Barange and Perry 2009; Sitoki et al. 2010; Ogutu-Ohwayo et al. 2016). Section 3.3 explores the influence of climate change on abundance, biology and life history and yield of fishes. Various examples from literature will be used to illustrate that climate factors contribute to changes in composition, diversity and yield of fishes in different African lakes (O'Reilly et al. 2003; Allison et al. 2007; Barange and Perry 2009; FAO 2010; Ndebele-Murisa et al. 2011, Marshall 2012; Marshall et al. 2013; Ogutu-Ohwayo et al. 2013, 2016; Natugonza et al. 2015). Section 3.4 examines the effects of climate variability and change on the physiology of fishes, phenological changes (timing of life history events) and regime shifts (how changes in climate might trigger unpredictable biological responses as ecosystems shift from one state to another). Section 3.5 looks at how climate variability and change influences species invasions and disease organisms (parasites and diseases interactions) including: life-cycle of parasites; relationship between temperature and susceptibility of fish species to parasite attacks and diseases; indirect effects of climate change on parasites and their hosts in aquatic systems through alteration in water levels, eutrophication and ultra violet radiation. Participants will learn from case studies which suggest that climate warming contributes to changes in host-parasite interactions and proliferation of parasites and diseases in both temperate and tropical regions (e.g., Marcogliese 2001; Cochrane et al. 2009; Macnab and Barber 2012; NaFIRRI 2013; Namboowa 2015).

3.4 Module 4: Implications of Climate Change on Aquaculture

This module will introduce participants to the potential impacts of climatic variability and change on aquaculture production. It will highlight potential impacts and the required adaptation strategies and mitigation measures.

3.4.1 Learning Objectives

By the end of the module, participants should be able to: (a) Discuss the relationship between climate change and aquaculture production; (b) Explain the direct and indirect influence of climate change on aquaculture; and (c) Discuss the adaptation strategies and mitigations measures needed to address the impacts of climate change on aquaculture.

3.4.2 Lecture Topics

Section 4.1 provides an overview of global, regional and national relevance of aquaculture to food, income and employment; trends in aquaculture production and consumption; aquaculture and climate change. Section 4.2 discusses impacts of climate change on aquaculture highlighting the potential positive and negative impacts of climate change on aquaculture; direct and indirect impacts on water, land, seed, feed and energy. Section 4.3 presents aquaculture adaptation and mitigations strategies including: aquaculture diversification; proper site selection and aquaculture zoning to reduce threats associated with climate change; assessment of the required adaptations of cultured species using lessons learnt from the expansion of farming species outside their natural range of distribution; identifying new disease interactions and measures to address them; identifying species that are better adapted to emerging conditions. Lectures will be supplemented with practical/field excursions to aquaculture facilities to observe and discuss possible effects of extreme climate events like drought and floods on aquaculture farms.

3.5 Module 5: Livelihoods, Impacts, Adaptations and Mitigation

This module introduces participants to the impact of climate variability and change on livelihoods of fishers, adaptations strategies and mitigations measures needed to address the impacts, constraints to adaptation and the required interventions. It will cover initiatives such as the Clean development mechanisms (CDM); Reducing emissions from deforestation and forest degradation (REDD) and Land use, land use change and forestry (LULUF) that can contribute to reduction of greenhouse gases.

3.5.1 Learning Objectives

By the end of the module, participants should be able to: (a) Discuss socio-economic characteristics and livelihoods of fishers; (b) Describe the impacts

of climate variability and change on livelihoods of fishers; (c) Discuss adaptation strategies and mitigation measures that can be applied by fishers to mitigate impacts of climate variability and change; (d) Identify the constraints to adaptation and mitigation and the required interventions; (e) Design appropriate climate adaptation and mitigation initiatives at local community level.

3.5.2 Lecture Topics

Section 5.1 will provide an overview of socio-economic characteristics and livelihoods of fisher and riparian communities. The livelihoods will include fishing, boat renting, gear renting, fish trading, fish processing, boat crew and others including those out of fisheries. Section 5.2 will examine impacts of climate variability and change on fisheries livelihood assets, activities and outcomes. Section 5.3 will address adaptation strategies such as migration, changing fishing gear, using more nets, changing target species, reverting to non-fishing activities, exiting the fishery, changing fishing grounds, and increasing time on fishing grounds. Section 5.4 will highlight mitigation measures used to address impacts of climate change including tree planting; protection of wetlands and riparian zones; mulching gardens; and fuel efficiency. Section 5.5 will identify constraints to adaptation and mitigation and how they can be overcome. Section 5.6 will introduce participants to other climate adaptation and mitigation initiatives such as CDM, REDD and LULUF. The lectures will be illustrated with practicals, field visits and case studies on impact of climate change on fisheries and livelihoods of fishers and adaptation and mitigation strategies (e.g., Aiken et al. 1992; Broad et al. 1999; Jallow et al. 1999; Sarch and Allison 2000; Turner et al. 2007; Badjeck 2008; Badjeck et al. 2009; Iwakasi et al. 2009; Ogutu-Ohwayo et al. 2013; Musinguzi et al. 2016).

3.6 *Module 6: Aquatic Ecosystem Modeling in relation to Climate Change*

This module equips participants with skills for designing and implementing ecosystem models for research to inform fisheries policy and decision making. Specifically, it aims at creating awareness of uses and limitations of different modeling approaches and developing skills required to construct ecosystem models and to use them to study ecosystem dynamics and biogeochemical processes in aquatic systems to guide prediction of changes in the ecosystem. Participants will learn how to develop models using Ecopath with Ecosim (EwE), an ecosystem level model that has been widely used to address ecological questions, management policy options and effects of environmental changes such as those that may be brought about by climate change. The above model will be coupled with other

models like the Multi-scale Integrated Model of Ecosystem Services (MIMES) to accommodate nonlinear and indirect effects to explore the effects of climate change on human and natural systems coupling under varied climate change scenarios.

3.6.1 Learning Objectives

By the end of the module, participants should be able to: (a) Identify the strengths and weaknesses of using ecosystem models as a means of studying changes in aquatic ecosystems; (b) Design different ecosystem models for developing relationships between different components of the ecosystem; (c) Evaluate the performance of the models applied to the ecosystems; (d) Assess different available models to describe ecosystem responses to stress and inform decision making and policy.

3.6.2 Lecture Topics

Section 6.1 introduces ecosystem modeling and its significance in fisheries including: the purpose of ecosystem modeling; model formulation and parameterization; analysis of model outputs and validation model inter-comparisons; and importance and limitations of ecosystem modeling. Section 6.2 presents ecosystem models and their applications focusing on components of fisheries ecosystems and their inter-comparisons, models and their application for the different ecosystems components, their strengths and weaknesses. The emphasis will be on when, where and how different systems can be modeled. It will also involve defining and scoping research problems addressed by each model, formulation of conceptual diagrams, their strengths and weaknesses and validation. Section 6.3 explores data inventories for ecosystem modeling including: data types and sources for different models; data availability and gaps in Uganda's aquatic ecosystems and fisheries; and limitations and challenges in data availability. Section 6.4 presents Ecopath with Ecosim (EwE) as a major ecosystem modeling tool and provides an introduction to the trophic modeling software, Ecopath and its ecological network analysis interface, development of models using EwE, modeling and dynamics of aquatic ecosystems. This will give the participants an understanding of the theory behind the software and the confidence to construct and interpret basic ecosystem models.

3.7 Module 7: Policies for Addressing Climate Change on Inland Aquatic Systems

This module introduces participants to available policies that are applicable to address impacts of climate variability and change and associated stressors.

It emphasizes how the policies can be improved or revised to accommodate changes due to climate variability and change, including policies specific to climate change and those targeting management of the resources impacted by climate change such as land use, forestry, wetlands, water and fisheries.

3.7.1 Learning Objectives

By the end of the module, participants should be able to: (a) Articulate the international, regional, and national policies that can be applied to address climate change and resources impacted by it; (b) Discuss the application of different policies and the possibilities for their improvement to address climate change and impacted resources; (c) Design strategies, action plans and institutional frameworks for implementing the policies.

3.7.2 Lecture Topics

Section 7.1 provides an overview of International policies and legal instruments including the United National Framework Convention on Climate Change (UNFCCC); the Kyoto Protocol; the Vienna Protocol for Protection of the Ozone layer; the Montreal Protocol on ozone layer; and the Convention to Combat Desertification; the World Heritage Convention; the Convention on Wetlands of International Importance, the Ramsar Convention; the Convention on Biological Diversity (CBD); the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES); the Convention on the Conservation of Migratory Species of Wild Animals; the Code of Conduct for Responsible Fisheries; the International Plan of Action on Illegal, Unregulated and Unreported (IUU) fishing; and the International Plan of Action to Regulate Fishing Capacity.

Section 7.2 presents regional legal instruments that include: the African Convention on Conservation of Nature and Natural Resources under the AU; the African Union Strategy on Climate Change, the Treaty for the Establishment of the East African Community; the East African Community (EAC) Climate Change Policy; the Protocol on Environment and Natural Resources Management; The Protocol for Sustainable Development of Lake Victoria Basin; the Convention for Establishment of Lake Victoria Fisheries Organization; the Regional Plan of Action to prevent, deter and eliminate Illegal Un-regulated and Unreported fishing (IUU); and the Regional Plan of Action for Management of Fishing Capacity (RPOA-Capacity).

Section 7.3 presents national legal instruments including: the Constitution of the Republic of Uganda; the Uganda National Climate Change Policy; the National Environmental Policy and Statute; the Land Act; the National Forestry Policy and the National Forestry and Tree Planting Act; the National Policy for the Conservation and Management of Wetland Resources; the Water Policy; National Fisheries Policy and the Fish Act and associated regulations. Section 7.4 lists

institutional frameworks to implement the above instruments including secretariats, national ministries and departments for implementing the policies at international, regional, national and local levels.

4 Conclusions

Incorporating climate change into training curricula of tertiary education institutions is critical to building capacity and knowledge required to understand implications of the increasing variability and change in climate for fisheries, and adaptation and mitigation measures required to reduce the impacts on resources and livelihoods. This paper demonstrated that climate change was little understood and appreciated and requires concerted effort to promote it. In addition, addressing impacts of climate change effectively needs a multi-disciplinary and multi-sectoral approach that encompasses the entire process from climate factors to physical and chemical processes, primary and secondary productivity, fishery productivity, livelihoods, adaptation and mitigation measures, policy, and awareness raising. Furthermore, evidence from the paper points to inadequate knowledge, training and institutional capacity to address impacts of climate change on fisheries in most African countries. There was therefore need to build human resources capacity that can generate knowledge and increase awareness on climate variability and change in inland aquatic systems and livelihoods through mainstreaming climate change in the curriculum of training institutions. To address the inadequacy in human resources capacity, the future plan is to test the curriculum and training manual in tertiary institutions in Uganda and improve it over time. A strategy for continued training of young scientists has also been developed to provide a critical mass of manpower to continue addressing impacts of climate change on fisheries. The tools developed for addressing climate variability and change in inland aquatic and riparian ecosystems will also be up-scaled to larger lakes within Uganda and other aquatic ecosystems in Africa.

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