TECHNICAL, ECONOMIC AND ALLOCATIVE EFFICIENCY AMONG MAIZE AND RICE FARMERS UNDER DIFFERENT LAND-USE SYSTEMS IN EAST AFRICAN WETLANDS

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REG NO: A142/30818/2015

A THESIS SUBMITTED TO THE SCHOOL OF AGRICULTURE AND ENTERPRISE DEVELOPMENT IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL ECONOMICS OF KENYATTA UNIVERSITY

APRIL, 2019

DECLARATION

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This thesis is my original work and has not been presented for the award of a degree in any other university or any other award:

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DEDICATION

To my dear parents, brothers, and sisters.

ACKNOWLEDGMENT

I would like to convey my honest gratitude to the Almighty Father for the gift of life and salvation. I am very grateful to my University supervisors, Dr. Daniel Kyalo Willy and Dr. Lucy Ngare for their strong assistance as I developed my thesis. My truthful appreciation goes to all the lecturers at the Department of Agricultural Economics for their invaluable support. I must acknowledge the unwavering support that my colleagues, Lucy Gathoni Njogu and Mercy Ambe Ngum, accorded to me. Special thanks to Dr. Daniel Kyalo Willy and Dr. Helida Oyieke of the National Museums of Kenya for allowing me to carry out my research as part of the larger GlobE wetlands in East Africa project. My earnest gratitude goes to the German Federal Ministry of Education and Research (BMBF) for financing my study through the GlobE wetlands in East Africa project. To my dear parents, brothers and sisters, may our Almighty God bless you for the financial and moral support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

AE	:	Allocative Efficiency
ASAL	:	Arid and Semi-Arid Land
ASARECA	:	Association for Strengthening Agricultural Research in Eastern and Central Africa
CETRAD	:	Centre for Training and Integrated Research in ASAL Development
CD	:	Cobb-Douglas
CRS	:	Constant Returns to Scale
DEA	:	Data Envelopment Analysis
DMU	:	Decision Making Units
EE	:	Economic Efficiency
EUR	:	Euro
FAO	:	Food and Agriculture Organization of the United Nations
GDP	:	Gross Domestic Product
GOU	:	Government of Uganda
GR	:	Gross Ratio
IFAD	:	International Fund for Agricultural Development
IFPRI	:	International Food Policy Research Institute
IRRI	:	International Rice Research Centre
IWMI	:	International Water Management Institute
KALRO	:	Kenya Agricultural and Livestock Research Organization
KATRIN	:	Kilombero Agricultural Training and Research Institute
Kg ha^{-1}	:	Kilogram per hectare
KM	:	Kilometer
KPL	:	Kilombero Plantation Limited
KSC	:	Kenya Seed Company
MLE	:	Maximum Likelihood Estimation

MOAAIF	:	Ministry of Agriculture Animal Industry and Fisheries
MOALF	:	Ministry of Agriculture, Livestock and Fisheries
MT	:	Metric Tons
NAADS	:	National Agricultural Advisory Services
NACRRI	:	National Crops Resources Research Institute
NAFIS	:	National Farmers Information Service
NARO	:	National Agricultural Research Organization
NEPAD	:	New Partnership for Africa's Development
NERICA	:	New Rice for Africa
NGO	:	Non-Governmental Organization
SAA	:	Sasakawa Africa Association
SAGCOT	:	Southern Agricultural Growth Corridor of Tanzania
SSA	:	Sub-Saharan Africa
SFA	:	Stochastic Frontier Analysis
T ha^{-1}	:	tons per hectare
TE	:	Technical Efficiency
UBS	:	Uganda Bureau of Statistics
USAID	:	United States Agency for International Development
VRS	:	Variable Returns to Scale
WARDA	:	West Africa Rice Development Association
WFP	:	World Food Programme

OPERATIONAL DEFINITION OF KEY CONCEPTS AND TERMS

Productivity – refers to the ratio of production output to constraining resources (inputs) in East African wetlands

Technical efficiency – refers to how best the resources (inputs) available in a farm are converted into products (outputs) which represent productivity

Allocative efficiency – shows the ability of a producer to allocate the best proportions of inputs while considering the prevailing prices

Economic efficiency – Economic efficient farmers produce maximum output with minimal production costs and thus they are both technical and allocative efficient.

Wetlands – Include areas of shallow water bodies, fen, marsh, and peatland. In this study, they include the lowland floodplain of Kilombero in Tanzania, the inland valley bottoms of Namulonge in Uganda, and the highland floodplain of Ewaso Narok in Kenya.

Land-use – refers to management and alteration of natural surroundings into the built environment including settlements and semi-natural habitations (for instance pastures and agricultural fields).

Land-use system – refers to a combination of land unit, land-use, and a land utilization type. In the current study, there are three agricultural land-use management systems (ALUMS) that include upland-rainfed, upland-irrigated, and wetland-only.

ABSTRACT

East African farmers have been facing low crop productivity as indicated by low yields of major staples, maize and rice, leading to food insecurity. As a result, the respective governments have offered solutions such as the introduction of high yielding maize and rice varieties. Farmers have expanded their farms into productive areas such as wetlands in an attempt to increase output to counter the effects of climate change complications, population pressure, and the declining productivity in the upland fields. Agricultural production is done under different agricultural land-use management systems including; upland-rainfed, upland-irrigated, and wetland-only. Continuous pressure on wetlands compromises wetlands' capacity to offer other critical ecosystem services. This calls for a need to enhance efficiency in production to strike a trade-off between food production and wetland sustainability. Productive efficiency will ensure increased output with reduced wetland degradation, especially from further drainage. The objectives of this study were to identify the determinants of productivity, assess technical, allocative, and economic efficiency under the different systems, and determine the factors influencing productive efficiency. Three wetlands (Ewaso Narok, Namulonge, and Kilombero) were purposively selected. A sample of 445 households was randomly selected using a semi-structured interview schedule in a household survey. Stochastic frontier analysis was used to analyze technical, allocative, and economic efficiency scores while a two-limit Tobit model analyzed determinants of productive efficiency. Results indicate that maize farmers under the upland-irrigated system had a relatively higher technical efficiency at 52% level. Those under the wetland-only system had the highest mean allocative efficiency and economic efficiency levels of 59% and 35% respectively. Maize farmers under upland-rainfed system could proportionally save resources up to 59% by operating on wetlands best technical efficiency frontier of 93% level. Rice farmers had technical, allocative, and economic efficiency of 59%, 72%, and 46% levels respectively. Those operating at the mean technical efficiency could have inputs saving up to 37% of the resources by operating on the wetlands best frontier of 94% level. The study concludes that the upland-irrigated system is associated with the highest maize productive efficiency and that there can be a sustainable expansion of land in rice production in Kilombero wetland. The study recommends that governments and other stakeholders should ensure interventions that guarantee agricultural extension and formal education, which are necessary for improved maize and rice productive efficiency. National and county governments should encourage sustainable maize production under the upland-irrigated system especially with subsidized alternative water sources to enhance farmers' efficiency and sustainable agricultural production in wetlands. There should be an intervention to enable farmers to use optimal fertilizer amounts in rice production to enhance sustainable expansion of rice production with minimized degradation and drainage.

CHAPTER ONE

INTRODUCTION

1.1 Background

Low agricultural productivity and food insecurity are the two key issues that East Africa is endeavoring to address (FAO, IFAD, & WFP., 2015). Low agricultural production accounts for poverty among many rural inhabitants given that agricultural sector provides employment to closely 75%, 80%, and 66% of the population in Kenya, Tanzania, and Uganda respectively (IFAD, 2014; MoAAIF, 2011). Agriculture also provides approximately 30%, 50%, and 21% of Gross Domestic Product (GDP) in Kenya, Tanzania and Uganda respectively (Cervantes-Godoy & Dewbre, 2010; NEPAD, 2013; Salami *et al*., 2010; UBS, 2014). Besides the national efforts, a number of international bodies such as the International Fund for Agricultural Development (IFAD) and Food and Agriculture Organization (FAO) are striving to improve agricultural productivity in the region (FAO, IFAD, & WFP., 2015). Low productivity affects major staple food crops, which include maize and rice.

Maize (*Zea mays*) is the main staple in Kenya and Uganda (Macauley, 2015). To improve its productivity, Kenya Agricultural & Livestock Research Organization (KALRO) and Kenya Seed Company (KSC) among other organizations have introduced high yielding varieties such as KS-DH13, KS-H6217 and KH 600-23A in recent past years. Productivity, however, remains low with an average yield of 1.8 tons per hectare (t ha^{-1}) in comparison to a possible yield of over 6 t ha^{-1} (One Acre Fund., 2015; Schroeder *et al*., 2013). Annual maize production in Kenya is approximately 3.2 million MT while the consumption is about 3.5 million MT (FAO, 2017). Within the study area of Ewaso

Narok wetland, extension services offered by the National Farmers Information Service (NAFIS) and the extension officers from Laikipia county government to enhance maize productivity include the development of compost manure, crop protection, and use of agrochemicals.

The National Agricultural Research Organization (NARO) of Uganda has also released high-yielding, drought tolerant, and pests and diseases resistant maize varieties in the past years. This is in the effort to address low maize productivity, which has been attributed to low-yielding varieties, pests, diseases, and adverse climatic conditions. However, the yield stagnates at 1.5 t ha^{-1} in comparison to a possible yield of 7 t ha^{-1} (Okoboi, Muwanga, & Mwebaze (2012). Annual national maize production is about 1.6 million MT while the consumption is about 1.8 million MT (FAO, 2017). The deficit is addressed through imports. Within the Namulonge wetland, the National Crops Resources Research Institute (NaCCRI) have been developing new maize varieties such as Longe 10 and Longe 11 while the extension and advisory services are provided by National Agricultural Advisory Services (NAADS) (Naluwairo, 2011). Also, the wetland is one of the wetlands that are undergoing quick transformations especially due to agricultural activities in Uganda (Tumuhimbise, 2017).

Rice *(Oryza sativa* L.) in Tanzania is ranked second among the staple food crops after maize. According to Sekiya *et al*. (2013), farmers produce below 2.0 t ha^{-1} with a possibility of over 5.6 t ha^{-1}. The low rice productivity in Tanzania has been attributed to the poor dissemination of technology, low yielding varieties of rice, and the effects of climate change on natural environment among other factors (Rugumamu, 2014). There have been the introduction of yield-enhancing NERICA (*Oryza glaberrima*) varieties

(Africa Rice Center (WARDA)/FAO/SAA, 2008). Low productivity also persists in the study area despite the introduction of high-yielding varieties (Styger, 2012). The annual production of rice is about 1.8 million MT while the consumption is approximately 1.9 million MT (USDA, 2017). Within the Kilombero wetland, the International Rice Research Centre (IRRI) and Kilombero Agricultural Training and Research Institute (KATRIN) have introduced pest and disease resistance as well as high-yielding varieties such as TXD 88, TXD 305 and Nerica (Styger, 2012). Kilombero Plantation Limited (KPL) in partnership with United States Agency for International Development (USAID) provides inputs to many farmers within the wetland. The Tanzanian government has a plan of expanding rice production within the Kilombero wetland through an initiative called Southern Agricultural Growth Corridor of Tanzania (SAGCOT) by establishing 16 irrigation schemes for the next 20 years (Smith, 2016).

One of the farmers' techniques of increasing crop production is to expand agricultural lands into fragile ecosystems such as wetlands (Turyahabwe *et al*., 2013). Wetlands are distinguished by water availability either seasonally or permanent. Water is also found either within the root zone or at the ground surface (Mitsch & Gosselink, 2007). The recent increase in household food production, the creation of revenue for a number of rural families, and provision of food for the urban population in Sub-Saharan Africa (SSA) have largely been attributed to the expansion of agricultural lands into productive wetlands (FAO, 2012). In drier areas such as Laikipia (a semi-arid area), particularly during the dry season, basic supplies such as food and water are only harvested within the wetlands.

Wetlands play other critical ecosystem functions such as provisioning, regulating, cultural and supporting services (see Appendix 1). However, human activities hamper the natural processes and speed up wetlands degradation and thus compromising their continued existence. The activities include agriculture, large water infrastructure projects such as dams, urban development, and water extraction for industries (IWMI, 2014). Agriculture is the most significant threat to wetlands because farmers have widely and permanently transformed wetlands in order to enhance their agricultural productivity (McCartney *et al*., 2010). The transformation had contributed to between 64% and 71% of the world's wetlands loss by 2014 (Gardner *et al*., 2015). It is very critical to reconcile food production with the sustainability of wetlands in East Africa to ensure their continued existence.

Wetlands are regulated by government agencies to ensure that their conservation and sustainability. In Kenya, the Ministry of Environment and Mineral Resources uses the Water Services Regulatory Board and Water Resources Management Authority in wetland conservation matters (GOK, 2013). The National Environmental Management Council of Tanzania manages wetlands through the National Wetlands Technical Committee, although at its embryonic stage (Majamba, 2004). The Ministry of Water and Environment of Uganda through the National Environment Management Authority and Wetlands Management Department manages the wetlands to ensure sustainable utilization (Businge, 2017). Encroachment and degradation of wetlands exist despite their protection by government agencies as farmers engage in agricultural activities (Thenya *et al*., 2011).

Crop production within and around wetlands is under different agricultural land-use management systems namely upland-rainfed, upland-irrigated, and wetland-only.

Some systems assist farmers in managing risks associated with agricultural production under unpredictable climatic conditions. Agricultural production under the upland-rainfed system has no direct impact on the wetland ecosystem because farmers depend on rain for water. The effect is felt due to soil erosion in the uplands and when agrochemicals leach to join the wetland ecosystem thus degrading water and soil. The upland-irrigated system may involve the use of wetland water in the irrigation of crops, especially in commercial farming. Producers may incur more cost under this system to set up and maintain the irrigation systems. The wetland-only system involves the creation and maintenance of canals in the wetlands to create arable farms from the marshes. The system directly interferes with the natural processes, such as hydrology and soil formations, that take place in wetlands (Turyahabwe *et al*., 2013).

From the aforementioned information, food production in East African wetlands must be implemented in the most efficient manner to thwart more anthropogenic damages to the wetlands. This will ensure further support of wetlands to food security as well as the provision of the other critical ecosystem services. Productive efficiency must also be guaranteed for the expected impact of a new technology to materialize. This is because, enhancement of productive efficiency is a prospective basis of productivity advancement, failure to which the new technology could be futile when the existing resources are not used to the full potential (Chiona *et al*., 2014; Ahmed *et al*., 2015). Once the farmers produce efficiently using new technologies, they do not necessarily have to encroach wetlands further to increase their output. Also, efficient production ensures a reduction of unsustainable agricultural intensification from improper inputs use that may exacerbate soil degradation (Willy *et al*., 2019).

1.2 Problem Statement

Agriculture is faced with growing pressure to reduce food insecurity and unemployment for the rising East African population. Consequently, farmers have strategized to expand agricultural land into fragile ecosystems such as productive wetlands in an attempt to increase food production and profit. This encroachment compromises the capacity of wetlands to perform other critical ecosystem functions. One approach of mitigating the negative impact of agriculture on East African wetlands is through encouraging practices that minimize the externalities while producing efficiently. Also, given that farmers engage in crop production under different agricultural land-use systems namely upland-rainfed, upland-irrigated, and wetland-only, there is a need to identify the system that is associated with the highest productive efficiency. This ensures appropriate resource usage, allocation, and producing at minimum cost. Productive efficiency is essential as it minimizes expansion of agricultural land into wetlands and detrimental intensifications as farmers attempt to increase their crop output under the different systems.

Several studies have highlighted the threat of anthropogenic degradation to wetlands (Schuyt, 2005; McCartney *et al*., 2010; Turyahabwe *et al*., 2013; Halima & Munishi 2009; and Gardner *et al*., 2015). The process is hastened by pressures associated with population density growth, urbanization, and changes in weather patterns. Besides all these dynamics, wetlands are still facing pressure from multiple competing uses and this requires productive efficiency to sustain their capacity. This begs the question; 1) Are farmers within and around East African wetlands producing efficiently? and 2) Which agricultural land-use management system (ALUMS) is associated with the highest productive efficiency? However, there is dearth of scientific studies on technical, allocative, and economic efficiency in the East African wetlands considering the different agricultural land-use management systems under which farmers engage in crop production. This is despite the wetlands contribution to food security and the continued threat of degradation to their existence. Further, determining the efficiency levels in each system can guide policy to develop targeted strategies on how to improve efficiency in wetland farming since blanket approaches may not bear the targeted fruits.

1.3 Objectives

The broad objective of this research was to assess the technical, allocative and economic efficiency among rice and maize farmers in East African wetlands.

1.3.1 Specific Objectives

1. To identify the inputs that contribute most to maize and rice output in East African wetlands
2. To assess the technical, economic and allocative efficiency among maize farmers under different land-use systems in East African wetlands
3. To assess the technical, economic and allocative efficiency among rice farmers in East African wetlands
4. To determine the socio-demographic, economic and institutional factors influencing the economic efficiency (EE), technical efficiency (TE), and allocative efficiency (AE) among East African wetlands' maize and rice farmers

1.4 Research Hypotheses

i. All inputs in rice and maize production do not significantly contribute to output in East African wetlands
ii. There is no statistically significant difference in mean TE, AE, and EE among maize farmers under different land-use systems in East Africa
iii. Rice farmers in East African wetlands do not operate on the production frontier
iv. Socio-demographic, economic and institutional characteristics have no significant influence on TE, EE, and AE of wetland maize and rice farmers in East Africa

1.5 Significance of the Study

This research is important to the agricultural sector as it provides key information on efficiency in resource utilization and the production factors that need to be targeted for increased crop productivity in these productive wetlands. Farmers have the information that can guide their resource management in wetlands and as a result, food production in wetlands will increase. The increased wetland farmers' TE, AE, and EE are crucial for enhancement of food security in East Africa where drought is a perennial phenomenon in many parts of these countries. Against the backdrop, any improvement in rice and maize productivity in East African wetlands has the potential to contribute immensely to regional and household food security while increasing household income for the agricultural dependent rural population.

The findings are important for policy interventions by policymakers, which can enhance sustainable utilization of wetlands for future food production and provision of other ecosystem services in East African wetlands. Researchers, extension service providers, and Non-Governmental Organizations (NGOs) should use information from this study to address the areas necessary for the improvement of crop productivity within the wetlands through productive efficiency at a farmer level. They should advise farmers on the most effective ways to maximize their output with minimal wetland degradation to avoid more degradation of wetlands. The study also forms a basis for other studies pertaining to wetlands' crop farming in the rest of the world based on the recommendations.

1.6 Theoretical Framework

The theoretical framework used in the current study was borrowed from the approach of productive efficiency measurement as proposed by Farrell (1957). Productive efficiency denotes how best a farmer utilizes the available resources in the production process. Let us assume that a farm is employing two inputs, namely *X1* and *X2* in the production of one output, with the production process faced by constant returns to scale. The assumption allows a simple isoquant in Figure 1.1, which represents a diagrammatic representation of AE, EE, and TE, to be presented by incorporation of appropriate information.

A technically efficient farm combines two inputs to produce one unit of output as depicted by the isoquant *SS'*. Point *P* on the diagram shows the two inputs that are used to produce a unit product (output) on the farm. Point *Q* depicts another farm that uses the same combination of the two inputs as farm *P*. Farm *P* produces similar output as farm *Q* but uses much of each input by a fraction *OQ/OP*. A technically efficient farm has the ratio *OQ/OP* equal to 1 and the inefficient farm has the ratio with a value of less than 1(Chiona *et al*., 2014). The difference between the estimated TE and 1 (one) shows the proportions of both inputs that must be reduced for a farm to produce efficiently.

Allocative efficiency (AE) estimation is also important in order to measure the level to which a farm uses the best combination of a range of inputs considering the prevailing market prices. This aims at maximizing profits. The ratio of the prices of the two inputs forms the gradient of the isocost *AA'*, which represents the minimum expenditure that a profit-maximizing firm should embrace. AE is depicted by *OR/OQ* ratio. Farmers producing at point *P* are allocative inefficient because the ratio *OR/OQ* is less than one. An allocative efficient farm must have its ratio *OR/OQ* equal to 1.

Economic efficiency is a product of both technical (*OQ/OP*) and allocative efficiency (*OR/OQ*) given by (*OR/OP*). This is due to the theoretical reduction in costs because of the decline of input proportions from *P* to *R*. As such, for a technically and allocative inefficient farmer to gain economic efficiency s/he should produce at *Q'*. This is the point of tangency for both the isoquant curve and the isocost, which forms the optimal point. At this point, the farm exhibit both TE and AE and therefore attains EE.

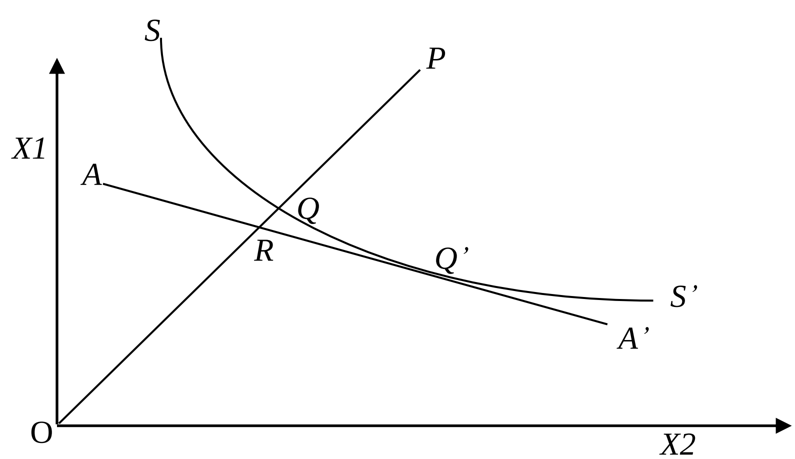

Figure 1. 1: Diagrammatic representation of technical, economic, and allocative efficiency
Source: Adapted from (Chiona *et al*., 2014; Farrel, 1957)

1.7 Conceptual Framework

The conceptual framework that was used in the current study utilized the production theory. Production refers to the process of transforming inputs (resources) into outputs with a given level of technology (Malinga *et al*., 2015). The transformation of inputs into outputs in the production process is normally illustrated by a production frontier ($f(x_i; \beta)$). As such, the frontier shows the maximum output achievable from different combinations of inputs. Its dual function (cost function) illustrates the cost-minimizing input levels. To attain maximum output, both rice and maize farmers within the wetlands have to be efficient in their production process. Efficiency in this regard refers to the production of a maximum output using the same combination of inputs at minimal cost (Kibirige, 2014).

Both rice and maize outputs are indirectly influenced by the policy environment, which is characterized by political and economic dynamics in the respective East African countries. Maize and rice outputs in the East African wetlands depend on availability and distribution of inputs, which are influenced by the policy framework in the respective countries. The more the production factors that wetland farmers use, including land, agrochemicals, and seeds, the higher the anticipated output. As such, there is a risk in overusing the available resources, which may result in negative effects on yields. Expansion of land input may as well endanger the existence of wetlands in East Africa. Optimality in resource allocation and use is hence fundamental with regard to the levels that maximize output while minimizing production cost.

Technical, economic and allocative efficiency influence the output of wetland maize and rice farming. For farmers to increase their TE, EE and AE, the manner and the proportions in which they utilize their resources are important, considering the prevailing factor prices. Further, institutional and socio-economic factors determine farmers' productive efficiency. Socioeconomic factors such as farmers' experience, gender, off-farm income, and education of the farmers also affect their productive efficiency. Similarly, institutional factors such as group membership, credit access, market access, and extension services influence their TE, AE, and EE. For instance, wetlands farmers who belong to organized groups may receive training on better crop husbandry and get linked to product markets and thus they increase the TE and EE. Further, farmers who access credit may have an increased capacity to afford yield-enhancing inputs such as fertilizers and certified seeds.

Technical, allocative and economic efficient farmers improve production output and incur minimum production cost, and thus improved household income. They can now afford more inputs while the policymakers can adjust policies pertaining to improved productivity of wetland maize and rice farming so that farmers can minimize degrading and expanding agricultural lands into these fragile ecosystems in an attempt to increase the output. The anticipated outcomes include sustainable production in wetlands, improved food security, and profitable agricultural enterprises under all the agricultural systems.

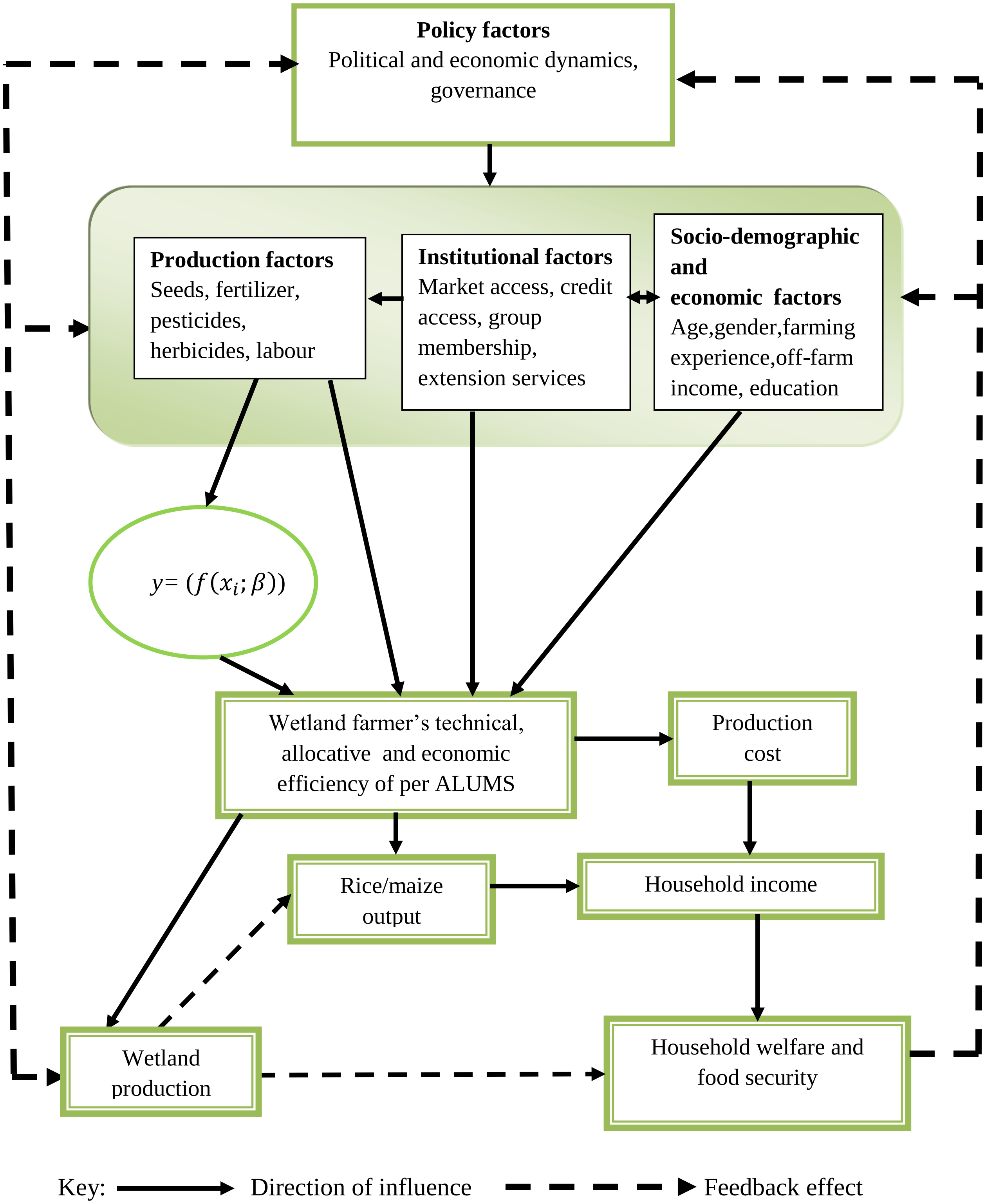

Figure 1. 2: Conceptual framework showing maize and rice production in East African wetlands
Source: Adapted from (Sibiko, 2012)

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The chapter entails the literature review of productivity, technical, allocative, and economic efficiency. In addition, methods of measurement of efficiency are reviewed. The empirical studies on technical, allocative, and economic efficiency are critically reviewed.

2.2 Productivity and Efficiency

Productivity is the ratio of production output to constraining resources (inputs) (Sibiko, 2012). The measure of productivity is the total output per unit of total input (Fried *et al*., 2008). According to Coelli *et al*. (2002), productivity varies depending on the scale of operation, operating environment, production technologies, and operating efficiency. Productivity is simply a measure of productive efficiency. Similarly, according to Malinga *et al*. (2015), an increase in the efficient use of resources in the production process influences productivity. To enhance productivity, the efficiency of resource use must accompany the intensification of agriculture in the wetlands as farmers increase the use of technology in production.

Technical efficiency (TE) is explained by how best the resources (inputs) available in a farm are converted into products (outputs) which represent productivity (Malinga *et al*., 2015). Technical efficiency assesses whether the transformation of inputs achieves maximum output or attainment of maximum production without waste of resources. Allocative efficiency (AE) shows the ability of a producer to allocate the best proportions of inputs while considering the prevailing prices (Degla, 2015; Mutoko *et al*., 2015). Economic efficiency (EE) is thus clearly stated as the farm’s capability of producing maximum output at the minimum cost with a consideration of current technology for profit maximization (Aboki *et al*., 2013).

2.3 Measurement of Efficiency

2.3.1 Data Envelopment Analysis (DEA)

DEA model was formulated by Charnes *et al*. (1978) who carried on the seminal work of Farrel (1957) to incorporate many inputs and outputs simultaneously. DEA is a deterministic method used in measuring TE, which assumes all deviations from optimal output levels are due to inefficiency, rather than errors. According to Coelli *et al*. (2005), DEA uses the method of linear programming and creates a non-parametric frontier over sample data, and thereafter efficiency scores are then calculated in comparison to the frontier. Decision-Making Units (DMUs) are then compared to the best performer with a TE of 1 (Cesaro *et al*., 2009).

Data envelopment method does not impose functional forms on the production frontier, which is a conventional practice for the parametric stochastic frontiers (Karani-Gichimu *et al*., 2015). The method also differs from the parametric methods, as it does not make a priori assumptions. It makes the convexity and monotonicity assumptions creating room for a flexible frontier that enhance a functional form that is able to vary across all the DMUs. Despite the limitations of the deterministic DEA method, the approach has an advantage as it allows for the provision of information on input and output shadow prices of DMUs. It is also capable of handling multiple outputs and inputs, unlike SFA. The method nonetheless lacks robustness over outliers and its deterministic form makes it impossible to test for hypothesis (Chimai, 2011).

2.3.2 Stochastic Frontier Analysis (SFA)

This model was independently proposed by Aigner *et al*. (1977) and Meeusen & Van Den Broeck (1977). It separates the error term from the estimation of production function into inefficiency effects and random variations due to statistical noise and unlike DEA, it allows for hypotheses testing regarding the production structure and the level of inefficiency (Coelli *et al*., 2005). The most common model specifications of SFA are Cobb-Douglas (CD) and translog (Degla, 2015). In this study, the CD specification was used because it is self-dual and has been proven useful by many empirical studies related to agriculture in developing countries (Ogundari & Ojo, 2007; Tsue *et al*., 2012). Translog is faced by issues of collinearity due to increased numbers of variables as a result of multiplication of production factors during the model specification (Karani-Gichimu *et al.*, 2015).

2.4 Review of Studies Analyzing Technical, Economic, and Allocative efficiency

In a study to estimate EE and TE of rice producers in Kou Valley of Burkina Faso, Ouedraogo (2015) used SFA in a Cobb-Douglas production function with its dual cost function. Literacy levels significantly and negatively influenced TE of the farmers while farming experience influenced it positively. Both household size and farming experience influenced AE positively.

Ahmed *et al*. (2015) and Sibiko (2012) used the SFA and Tobit model to measure efficiency and determining the factors influencing efficiencies. Both allocative and economic efficiency were found to be positively determined by education. AE and EE were both negatively influenced by extension access, which positively influenced TE.

Access to credit was found by Sibiko (2012) to negatively influence TE unlike many other studies (Nyagaka *et al*., 2010; Amaechi *et al*., 2014; Ahmed *et al*., 2015).

Abiodun & Omonona (2015) estimated the resource use efficiency of wetland farmers in Ibadan metropolis using budgetary and production frontier analysis. Most of the farmers' output variations resulted from the technical inefficiency effects in their production. Age of the farmer, education, and household size increased wetland farmers' TE. It was recommended that farmers should continue with wetlands farming because it was profitable.

Ogundari & Ojo (2007) used stochastic production and cost function model to estimate farm level technical, allocative and economic efficiency of small farms in Nigeria. TE, EE, and AE emerged at 0.903, 0.89 and 0.807 respectively. Technical efficiency appeared to be more significant than AE as a source to gain highest EE.

In a study to estimate AE and TE of Zambian smallholder maize farmers, Chiona (2011) used the DEA method. Utilization of chemical fertilizer had a positive influence on TE although less than half of the farmers used it. Other factors that determined the level of EE include; extension services access, household size, hybrid seeds, household head education, and farm size. It was suggested that the encouragement of farmer groups formation and strengthening was necessary in order to advance market information and agricultural extension accessibility.

Sanyang (2014) assessed the technical, allocative and economic efficiency of rice farmers in Central Gambia using a Cobb-Douglas production function and its dual cost model. Inefficiency was found among farmers. The mean TE, AE, and EE were 65%, 67%, and 46%. It was noted that there was considerable room for improvement of productive efficiency through better use of existing technology and the available resources. It was recommended that policy should address accessibility of fertilizer and extension facilities.

A study to assess resource-use efficiency was carried out by Girei *et al*. (2013) in the Adamawa state of Nigeria using SFA. The maximum likelihood estimates revealed that land, fertilizer, and labor were significantly influencing food crop output. The mean TE, AE, and EE were 71%, 76%, and 54% respectively. The recommendation was given to the government and other key agencies to intensify their advisory services and introduce pre-job and mentorship training programmes. This would help to increase productive efficiency.

An analysis of the economic efficiency of Nigerian small-scale farmers was done by Asogwa *et al*. (2011) using a parametric frontier approach. They found that TE, AE, and EE were 30%, 12%, and 36% respectively. Low availability of extension services access was found to be the greatest contributor to technical inefficiency. Inefficient farmer organizations were found to be the greatest cause of allocative inefficiency due to failure to enhance the collective action.

A study was done by Kibirige (2014) to estimate technical efficiency among smallholder maize farmers in Masindi district of Uganda using stochastic frontier production function. The study found that about 57% of the farmers had above 67% technical efficiency. Variety of seeds planted, spouse education, group membership, and household size among others were the major positive determinants of TE. It was recommended that each determinant should be addressed based on its sign for improved productivity and thus increased income and livelihoods.

Mutoko *et al*. (2015) assessed technical and allocative efficiency gains from integrated soil fertility management (ISFM) in maize farming system of Kenya. The study used a Cobb-Douglas production function specification and its self-dual to assess both TE and EE. Application of ISFM influenced both technical and allocative efficiency of maize farmers. Thus, they had an increased economic efficiency. In order to achieve maximum economic efficiency, it was recommended that policies that address extension education, market access, and off-farm income should be put in place. This should include dissemination of ISFM technology to other maize farmers to improve productive efficiency and returns.

2.5 Criticism and Research Gap

None of the studies assessed TE, AE, and EE of maize and rice production together with their determinants in East African wetlands under the different ALUMSs. Similarly, none of these studies considered the use of machinery such as a tractor in crop production despite the fact that it minimizes labor demand and drudgery associated with agricultural production (Asiimwe, 2009). On the other hand, Aboki *et al*. 2013, Kareem *et al*. 2008, and Ouedraogo, 2015 estimated cost efficiency as the allocative efficiency. From literature, cost efficiency is an inverse of EE (Ogundari & Ojo, 2007; Ouedraogo, 2015).

With regard to methodology, a study by Chiona, (2011), used a non-parametric DEA method. This method disregards the presence of random factors (e.g. weather variability, pests, and diseases) and measurement errors which are normal in SSA agriculture (Malinga *et al*., 2015). The Cobb-Douglas production functional form of SFA was used in the current study due to its self-dual function and thus allowing for the estimation of AE and EE. It allows for the inclusion of factors that are beyond farmers' control.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The chapter entails a description of the study area, sampling procedure and sample size, data sources and collection, and the analytical framework.

3.2 Study Area

Ewaso Narok wetland in Kenya is a highland floodplain located along the Eng'are Narok River, within Laikipia County (Thenya, 2001). The wetland starts at the Rumuruti-Nanyuki road and stretches about 17 Km up to the veterinary out span close to the Ol'Maisor ranch. The area experiences a semi-arid climate as indicated by its mean annual rainfall, which ranges between 400 mm and 840 mm (Mwita, 2013). Long rains in the area are experienced between March and May while short rains are received between October and November. There have been increasing incidences of cultivation of maize, tomatoes, and beans due to human population increase (Thenya *et al*., 2011). The wetland was purposively selected because the Ewaso Narok floodplain supports agriculture within a semi-arid area throughout the year and the wetland becomes a major source of human and animal food during the dry seasons (Mwita, 2013). Maps showing the study wetlands are presented in Appendix 2.

The Namulonge wetland is at Kyaddondo County in the Wakiso district of Uganda. The inland valleys are located at the site of National Crops Resources Research Institute (NACRRI) and extend to areas near Lake Kyoga, Lake Victoria, Jinja and Kampala around the Ugandan equator (Leemhuis *et al*., 2016). The area is characterized by broad valleys that are occupied with swamps and several flat-topped hills. The wetland experiences a sub-humid climate and receives a mean annual rainfall of 1170 mm. Mean temperature ranges from 15^0C to 30^0C (Nsubuga *et al*., 2011). Major crops grown are maize, sweet potatoes, beans, cassava, and bananas. The Namulonge inland valley wetland was purposively selected as the area occupied by the largest permanent wetlands between Lake Kyoga and Lake Victoria in Uganda. It is also one of the wetlands that are undergoing quick transformations especially due to agricultural activities (Tumuhimbise, 2017).

Kilombero wetland is a river floodplain of a valley close to Ifakara in Tanzania stretching over a distance of 250 Km and a width of approximately 65 Km along the banks of the Kilombero River, in the South-central parts of Tanzania. The valley and the marginal hills around it cover approximately 11,600 Km^2. This wetland experiences a sub-humid climate and receives a mean annual rainfall of approximately 1418 mm with a mean annual temperature of 24^0C (Kato, 2007). Rice, maize, green grams, bananas, and beans are the major crops produced in this wetland. The study site was purposively selected because the Kilombero wetland is a focus floodplain for the Tanzanian government due to its current capacity of sustaining rice production throughout the year (Mombo *et al*., 2011). The Tanzanian government has a rice production expansion plan through the Kilombero cluster of the Southern Agricultural Growth Corridor of Tanzania (SAGCOT) by establishing 16 irrigation schemes for the next 20 years (Smith, 2016).

Selection of these wetlands was purposive based on their importance in supporting anthropogenic activities (e.g. farming), and especially because they are threatened by such activities. There was also the consideration of diversity in wetlands' geomorphic attributes that includes inland valley landscapes (Namulonge), lowland floodplains (Kilombero) and highland floodplains (Ewaso Narok).

3.3 Sampling, Data Types, and Data Collection

Within each target wetland, a sampling frame was generated, which comprised of the households who were engaged in maize or rice farming within and around the wetland. It included a total of 2800 and 3500 maize farming households in Ewaso Narok and Namulonge wetlands respectively and about 2000 rice farming households in the Kilombero wetland. The primary data used for the current research were obtained through a cross-sectional survey of 445 randomly selected maize and rice-farming households located near the target wetlands. In Ewaso Narok and Namulonge, each wetland had 150 maize farming households randomly sampled while the Kilombero wetland had 145 rice farming households that were randomly selected. The sample size for the study was computed from the formula as used by Israel (1992) in equation (3.1):

$$n_o = \frac{N}{1+N(e^2)} \qquad (3.1)$$

Where; N = population of maize/rice farmers in the target wetland, e = level of precision, and n_o= sample size. For instance, the sample size for respondents from Ewaso Narok wetland was computed as 2800/$\{1 + 2800(0.08^2)\}$.

In Ewaso Narok and Kilombero wetlands of Kenya and Tanzania respectively, the sampling involved two stages because the wetlands were well defined. First, administrative officers and knowledgeable villagers assisted in listing all the villages located around the wetlands. Secondly, in order to ensure a reasonable representation of households across the entire wetland, villages were randomly sampled. A sampling frame was then developed from sampled villages and each village, proportional to its size, contributed to the drawing of a random sample of households. A total of 26 and 27 villages were sampled from Ewaso Narok and Kilombero respectively. Namulonge wetland had a different case because the area of study is dotted by many small wetlands and therefore, a three-stage sampling process was necessary. The first stage involved obtaining a map of all the wetlands in the study area from the Wakiso district environmental officer. The map assisted in listing all the major wetlands from which a random sample that ensured a reasonable distribution of wetlands coverage was drawn. With the assistance of the map, the selected wetlands were accessed and a list of 20 villages developed with the help of the village elders. Then, the sampling process of the households that were to be included in the survey followed. Data was captured in a pretested semi-structured interview schedule. Data captured included; gender, credit access, land-use systems, off-farm income, farming experience, education, age of the farmer, and household size among others.

3.4 Analytical Framework

3.4.1 Validation Tests

After estimating the maize and rice stochastic frontier models, tests of multicollinearity, heteroscedasticity, and missing variable bias were done. First, variance inflation factors (VIFs) were used to test for multicollinearity in the data (Ingabire, 2014). As a rule of thumb, a VIF value greater than 10 reveals the presence of multicollinearity in the data (Moranga, 2016). Secondly, *Breusch-Pagan / Cook-Weisberg* tests for heteroscedasticity were done where the null hypothesis was the assumption of homoscedasticity in data, $Var\varepsilon = E\lfloor\varepsilon - E(\varepsilon)\rfloor = \delta^2$. Lastly, *Ramsey* tests also known as Regression Specification Error Tests (RESETs) were used to test for missing variable bias in the maize and rice SFA models.

3.4.2 Determinants of Output, TE, EE, and AE among Maize and Rice Farmers

3.4.2.1 Assessment of TE and Determinants of Output

The stochastic frontier analysis (SFA) model that was independently formulated by Aigner *et al*. (1977) and Meeusen & Van Den Broeck, (1977) was used in this study. The model is formulated as follows:

$Y_i = f(x_i; \beta) + \varepsilon_i$ .... (3.2)

Where i =1,2,...,n and $\varepsilon_i = V_i - U_i$,

where Y_i represents the i^{th} farm output, $f(x_i; \beta)$ is a Cobb Douglas production specification, x_i is inputs vector for the i^{th} farm and β_i are the unknown parameters. ε_i represents error term composed of random error (V_i) which has zero mean and variance N(0;σ^2). V_i is associated with measurement errors and factors which a farmer does not have control over. U_i is the other component of ε_i and it is a random non-negative ($U_i \geq 0$) truncated half normal N(0;σ^2) variable that hinders a certain farm from achieving maximum output because it is associated with farm factors. It is associated with TE and ranges between 0 and 1. Technical efficiency is thus expressed as follows:

$\widehat{TE_\iota} = Y_i/Y_i^*$ .... (3.3)

where, Y_i^*= $f(x_i; \beta)$, the highest predicted output for the i^{th} farm.

The TE of the ith farm is expressed by the ratio of the observed production output to the highest predicted output (frontier output). It is expressed in equation (3.4).

$$\widehat{TE_i} = Exp\,(-^{u_i}) = {}^{Y_i}\!/_{Y_i^*} = \frac{f(x_i;\beta)\exp V_i - U_i}{f(x_i;\beta)\exp V_i} \text{ (Actual output/Frontier output)} \quad (3.4)$$

$$\text{Technical inefficiency} = 1 - TE \quad (3.5)$$

3.4.2.2 Assessment of AE and EE

The cost frontier of the self-dual Cobb Douglas function was formulated as follows:

$$C_i = g(Y_i, P_i;\ \alpha) + \ \varepsilon_i \text{ where i = 1,2,...n.} \quad (3.6)$$

where C_i is the overall production cost of maize or rice per hectare, Y_i represents the maize or rice output, P_i represents the cost of inputs, α represents a vector of unknown cost function parameters, and ε_i is the error term formulated as $\varepsilon_i = V_i + U_i$. Positive signs precede the error components because inefficiencies are known to raise production costs (Ogundari & Ojo, 2007).

Economic efficiency (EE) of the ith farm is represented by the ratio of the lowest frontier cost (C^*) to the actual cost *(C)* as shown in equation (3.7):

$$\text{EE} = \frac{C^*}{C} = \frac{E(C_i/u_i{=}0, Y_{i,}P_i)}{E(C_i/u_i, Y_{i,}P_i)} = E\left[exp.\,(U_{i,})/\varepsilon\right] \quad (3.7)$$

3.5 Empirical Model Specification

3.5.1 Stochastic Production Frontier Model

The model can be log linearized to be:

$$lnY_i = \beta_0 + \sum_{i=1}^{8} \beta_i \, lnx_i + V_i - U_i \qquad (3.8)$$

where, *ln* denotes natural logarithm, Y_i is the output in kgs per hectare, x_i are the input vectors, β_0 represents intercept, β_i are unknown production function parameters, and the rest were defined earlier.

The model that was estimated is as presented in equation (3.9):

$$ln\,Y = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \beta_5 lnX_5 + \beta_6 lnX_6 + \beta_7 lnX_7 + \beta_8 lnX_8 + (v_i - u_i) \qquad (3.9)$$

Where; *ln* denotes natural logarithm, Y is the i^th^ farm output, X_i represents maize or rice production inputs as shown in Table 3.1, and βi are the unknown parameters. Equation (3.9) was estimated using the maximum likelihood method to give estimates of βi, δ^2, and γ.

Table 3. 1: Variables in the stochastic production frontier model

Variable (X_i)	Measurement units	Expected sign
Output per hectare	**Kg ha^{-1}**	
Farm size under maize/rice cultivation	Hectares (ha)	+
Labor (family and hired)	Man-days ha^{-1}	+/-
Seed quantity	Kg ha^{-1}	+
Basal fertilizer	Kg ha^{-1}	+
Topdressing fertilizer	Kg ha^{-1}	+
Manure	Kg ha^{-1}	+
Pesticides	litre ha^{-1}	+
Herbicides	litre ha^{-1}	+

Gamma (γ) is also referred to as variance ratio and is given by $\left\{\sigma_\mu^2/(\sigma_\mu^2 + \sigma_v^2)\right\}$ or $\left\{\sigma_\mu^2/\sigma^2\right\}$. It is calculated to assess the level of inefficiency with a range between 0 and 1. Further, lambda (λ) that is $\left\{\sigma_\mu/\sigma_v\right\}$ is usually determined in order to evaluate the correctness of the specified normal/half-normal assumption and the goodness of fit.

According to Onumah *et al*. (2009), the rule that a male adult, a female adult, and a child (< 18 years) working for one day (8 hours) equal 1 man-day; 0.75 man-days; and 0.50 ma-days respectively man-days was used in computing the number of man-days. The ratios were employed in other studies, for instance, Battese *et al*. (1996) and Coelli & Battese (1996) used them in their researches.

3.5.2 Stochastic Cost Frontier Model

The cost frontier model that was estimated is as formulated in equation (3.10):

$$ln\, C_i = \alpha_0 + \alpha_1 lnP_1 + \alpha_2 lnP_2 + \alpha_3 lnP_3 + \alpha_4 lnP_4 + \alpha_5 lnP_5 + \alpha_6 lnP_6 + \alpha_7 lnP_7 + \alpha_8 lnP_8 + V_i + U_i \quad (3.10)$$

Where C_i represents the total production cost per hectare, P_1 to P_8 are the costs per unit inputs as shown in Table 3.2, and α_i are the unknown parameters, which were estimated.

Table 3. 2: Variables in the stochastic cost frontier model

Variable, (P_i in EURO ha^{-1})	Expected sign
Total production cost (C)	
Land rent	+
Labor wage	+
Cost of seeds	+
Cost of basal fertilizers	+
Cost of topdressing fertilizer	+
Cost of manure	+
Cost of pesticides	+
Cost of herbicides	+

The software program Frontier 4.1c was used to obtain the MLE estimates of the parameters in the functional form of the cost efficiency. This software estimates cost efficiency (CE), which is an inverse of equation (3.7). Farm EE is given as 1/CE and ranges between 0 and 1. AE is derived from the quotient of EE and TE as given by AE=EE/TE and takes a value between 0 and 1, that is $0 < \text{AE} < 1$ (Kolawole, 2007).

3.6 Assessing the Determinants of TE, AE, and EE

A two-limit Tobit was used to determine the socioeconomic and institutional factors that influenced technical, economic, and allocative efficiency as used by Ahmed *et al*. (2015), Nyagaka *et al*. (2010), and Sibiko (2012). Efficiency scores lie between 0 and 1 because they are double truncated at 0 and 1 and thus form the basis to adopt the Tobit model. According to Ahmed *et al*. (2015), Ordinary Least Squares (OLS) estimation method cannot be used because it gives biased estimates of parameters due to the assumption of normal distribution and homoscedasticity of the error term and the dependent variable.

The structural equation of the Tobit model is given as:

$$y_i^* = G_i\beta + \varepsilon_i \quad \text{.......... (3.11)}$$

Where y_i^* is the latent variable for the i^th maize or rice farm representing efficiency scores. G_i represents independent variables hypothesized to influence technical, allocative, and economic efficiency, β represents the unknown parameters, and ε_i is the error term with an assumption of having an independent and normal distribution with zero mean and variance (σ^2).

The observed y_i can therefore be generically defined as:

$$\left\{\begin{array}{l} y_i = y_i^* \ if\ y_i^* \geq \tau \\ y_i = \tau_y \ if\ y_i^* \leq \tau \end{array}\right\} \quad \text{.......... (3.12)}$$

The latent variable y_i^* is observed for values greater than τ and censored for values that less than or equal to τ. Tobit model is used for censoring the values both from minimum and maximum. The Tobit model utilizes τ as 0 (τ =0). It is also clear that technical, allocative, and economic efficiencies range between 0 and 1. The factor τ was substituted in the formula as shown in equation (3.13):

$$y_i = \left\{\begin{array}{l} 1\ \ if\ y_i^* \geq 1 \\ y_i^*\ if\ 0 < y_i^* < 1 \\ 0\ \ if\ \ y_i^* \leq 0 \end{array}\right\} \quad \text{.......... (3.13)}$$

It is clear that the model assumes a stochastic index ($G_i\beta + \varepsilon_i$) in which the values are only observed when they fall between 0 and 1. Any other variable value below 0 and above 1 are termed as an unobserved latent or hidden variable. Moreover, the dependent variable is continuous but not normally distributed since its values range from 0 to 1.

The variable agricultural land-use management system (ALUMS) contained three categories under the wetland maize production namely; upland-rainfed, wetland-only, and upland-irrigated. These were presented as dummies as follows; upland-rainfed as ALUMS1, upland-irrigated as ALUMS2, and wetland-only as ALUMS3. These were used to capture the variations in efficiency among maize farmers across the land-use systems. To avoid the problem of dummy variable trap, ALUMS3 was dropped and became the benchmark variable for the wetland maize production model (Irungu, 1998).

Equation (3.14) shows the empirical specification of the Tobit model for maize productive efficiency.

$$y_i^* = \beta_0 + \sum_{n=1}^{13} \beta_n Q_i + \varepsilon_i \qquad (3.14)$$

Where y_i^* represents the efficiency scores, β_n represents the unknown parameters, and Q_i represents the determinants of TE, AE, and EE as shown in Table 3.3. The dummy *wetland location* in the maize Tobit model was used to capture variations in productive efficiency if maize farmers produced either in Kenyan or Ugandan wetlands.

Table 3. 3: Variables used in the maize Tobit model variables

Variable (Qi)	Measurement units	Expected sign to TE, AE and EE
TE, AE, EE efficiency score	**%**	
Gender	Dummy (1= Female)	+/-
Age	Years	+/-
Education	Number of schooling years	+/-
Household size	Number of persons	+/-
Farming experience	Number of years	+
Extension access	Kilometers extension service provider	-
Credit access	Dummy (1=Yes)	+
Group membership	Dummy (1=Yes)	+
Off-farm income	Amount in EURO	+
Market access	Kilometers to product market	-
ALUMS1	Dummy (ALUMS1=1 if upland-rainfed)	+/-
ALUMS2	Dummy ALUMS2=1 if upland-irrigated)	+/-
Wetland location	1= Uganda and 0= Kenya	+/-

The empirical specification of the Tobit model for rice productive efficiency is as shown in Equation (3.15).

$$y_i^* = \beta_0 + \sum_{n=1}^{11} \beta_n H_i + \varepsilon_i \text{.......} \quad (3.15)$$

Where y_i^* represents the efficiency scores, β_n represents the unknown parameters, and H_i represents the determinants of TE, AE, and EE as shown in Table 3.4. Rice farming in the study area was done under the wetland-only system. In the rice Tobit model, the dummy *wetland location* captured the variations in farmers' productive efficiency if they produced either in Kilombero or Ulanga districts of Tanzania.

Table 3. 4: Variables used in the rice Tobit model variables

Variable (Hi)	Measurement units	Expected sign to TE, AE and EE
TE, AE, EE efficiency score	**%**	
Gender	Dummy (1= Female)	+/-
Age	Years	+/-
Education	Number of schooling years	+/-
Household size	Number of persons	+/-
Farming experience	Number of years	+
Extension access	Kilometers to the extension service provider	-
Credit access	Dummy (1=Yes)	+
Group membership	Dummy (1=Yes)	+
Off-farm income	Amount in EURO	+
Market access	Km to product market	-
Wetland district location	Dummy (1= Kilombero)	+/-

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter consists of two major sections. The first section entails discussions of the descriptive results comprising of household socio-demographic, institutional and economic characteristics. The section progresses by discussing inputs use in maize and rice production. The second section entails discussions of empirical results from the stochastic frontier analysis and the Tobit model. These include the discussions on determinants of output, efficiency scores and the factors influencing productive efficiency.

4.2 Farmer and Farm Attributes in East African Wetlands

Figure 4.1 presents the gender of the household head from the sampled farmers.

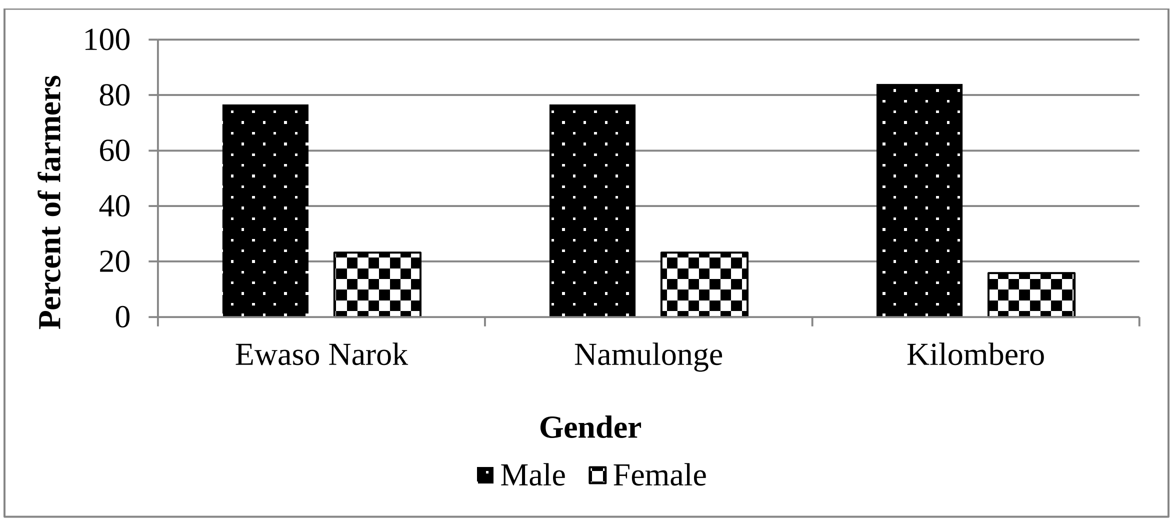

Figure 4. 1: Gender of the sampled household heads among maize and rice producers in East African wetlands.
Source: Author's survey data, 2017

Figure 4.1 shows that the majority of the East African wetland maize and rice-farming households were male-headed. For rice production in Kilombero wetland, 84.1% of the household heads were male. The number of men seems to dominate over that of women because most of the manual activities such as digging and maintaining canals are majorly done by men and women find it taxing.

The other farmer and farm attributes among maize and rice farmers in East African wetlands are presented in Table 4.1. They include age, household size, farming experience, and off-farm income among others.

Table 4. 1: Farmer and farm attributes

	Pooled (n=445)	Ewaso Narok (n=150)	Namulonge (n=150)	Kilombero (n=145)	
Attribute	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	F-value
Age	49.62 (13.41)	51.06 (14.05)	49.69 (12.5)	48.08 (13.56)	1.835
Education level	6.94 (4.51)	6.13 (5.06)	8.04 (4.82)	6.65 (3.19)	7.399***
Household size	5.47 (2.37)	5.39 (2.32)	5.81 (2.49)	5.2 (2.25)	2.626*
Household adults	2.71 (1.31)	2.77 (1.37)	2.74 (1.31)	2.61 (1.22)	0.608
Experience	13.58 (12.51)	15.21 (13.37)	8.61 (11.41)	17.03 (11.05)	20.2***
Farm size	3.42 (3.88)	2.44 (2.37)	2.63 (2.54)	5.25 (5.38)	26.382***
Land area under maize/rice	0.91 (1.37)	0.72 (0.83)	0.34 (0.31)	1.69 (1.9)	45.218***
Annual off-farm income	2142.18 (3054.45)	4913.96 (5271.45)	1207.75 (3346.54)	241.479 (562.33)	0.381
Assets value	4795.014 (12093.62)	3935.34 (15682.21)	5852.64 (9143.32)	4590.23 (10392.49)	0.973

***, **, *** statistic is significant at 10%, 5% and 1% level respectively**
Source: Author's survey data, 2017

The mean age of wetland maize and rice farmers was about 50 years. This implies that middle-aged farmers practiced most of the farming within the wetlands. The age of the farmer mostly positively correlates with his/her farming experience and thus indirectly influencing his/her productivity. Older farmers recognize the wetlands usefulness and potential for improved agricultural productivity better than their younger counterparts do.

The average number of schooling years for the wetland farmers was about 7 years. This implies that most of the farmers had acquired primary education, which means that they were literate. Literate farmers are able to apply some technologies in agriculture, which improves productivity and increases managerial abilities in terms of resource use.

Complex agricultural technologies may not easily be passed to most of these wetland farmers as they merely have primary education. Low education levels are inimical with regard to adoption of emerging technologies because farmers rarely acquire information from either the mass or the print media, thus forcing the extension agencies to make personal contacts with the farmers.

The average household size for the wetland maize and rice-farming households was about five persons. Relatively larger household sizes are good sources of labor and reduce dependence on hired labor. As such, households provided labor in the East African wetlands because about 50% of the members were adults.

Wetland farmers had an average of about 14 years of farming experience. This shows that most of them have crucial insights with regard to wetland agricultural production. It may also imply that the more the number of years a farmer engages in wetland agricultural production, the more the increased possibilities of farming in different locations within the wetlands.

The findings in Table 4.1 show that in the East African wetlands, about 0.91 Ha were put under maize and rice farming. Farmers in Kilombero used an average of 1.69 Ha in rice production. For maize production in Ewaso Narok and Namulonge wetlands, maize plots averaged at 0.72 Ha and 0.34 Ha respectively, and the sizes were significantly smaller compared to rice plots in Kilombero.

The average annual off-farm income for East African maize and rice farmers was about EUR 2142. This shows that some wetlands farmers engaged in other non-farm economic activities such as informal and salaried employment. Farmers earning off-farm income are likely to have the financial capability of purchasing agricultural yield-enhancing inputs and technologies.

The average value of household assets within the East African wetlands was approximately EUR 4795. Some of the assets such as machinery can influence agricultural productivity either directly or indirectly. Farm assets such as tractors, hoes, machetes, shovels, and wheelbarrows are used directly in crop production. On the other hand, assets such as cars, houses, water tanks, televisions, and radios among others may be used as collaterals by farmers in accessing loans that may be used to purchase yield-enhancing inputs and technologies (Maurer, 2014).

4.3 Agricultural Land-Use Management Systems

The different agricultural land-use management systems under which maize and rice wetlands farmers did their production are presented in Figure 4.2.

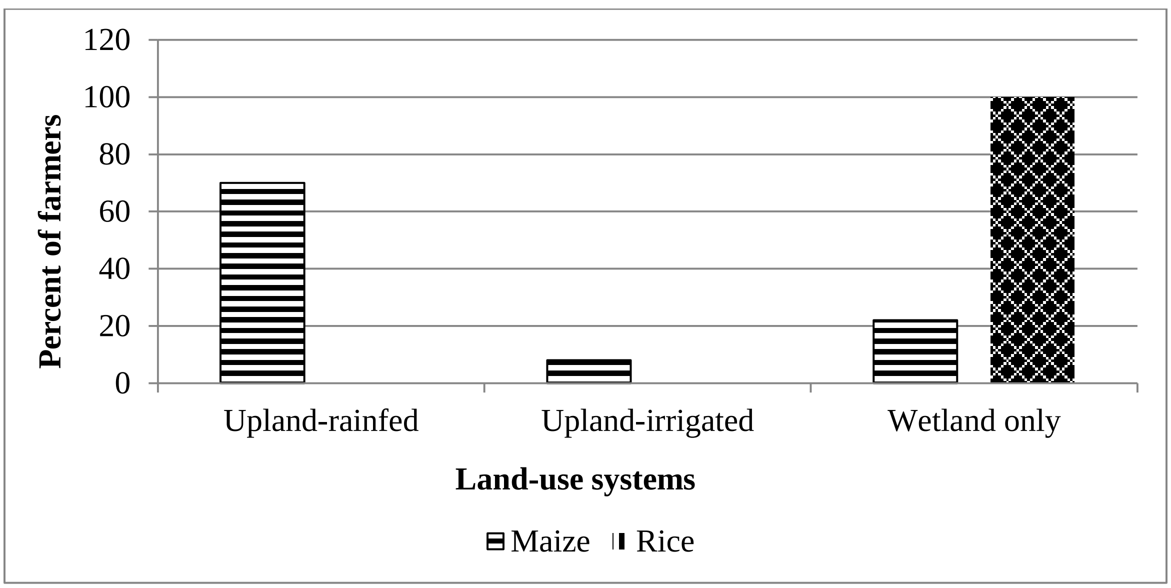

Figure 4. 2: Different agricultural land-use management systems, by percentages of farmers
Source: Author's survey data, 2017

The majority (70%) of the maize producers practiced farming under the upland-rainfed system. Despite the highest percentage of farmers observed under the upland-rainfed system, the research considers production under this system as critical due to potential wetland degradation that would result from intensifications on the upland fields. Only 8% of the households produced maize under the upland-irrigated system. Farmers practice farming under this system in order to capitalize on both dry and wet seasons. The system is ideally fit for management of risks associated with water scarcity and flooding during the dry and wet seasons respectively, thus the farmers may utilize the system for commercial farming. All the rice farmers in the Kilombero wetland practiced their farming under the wetland-only system. To expound on this, the Kilombero wetland is completely submerged during the wet season and consequently, only rice farmers can engage in farming under the wetland-only system.

4.4 Agricultural Management Practices and Inputs Use among Maize and Rice Farmers in East African Wetlands

4.4.1 Agricultural Management Practices and Input Types among Maize Farmers

Figure 4.3 presents the findings of land preparation methods in maize production.

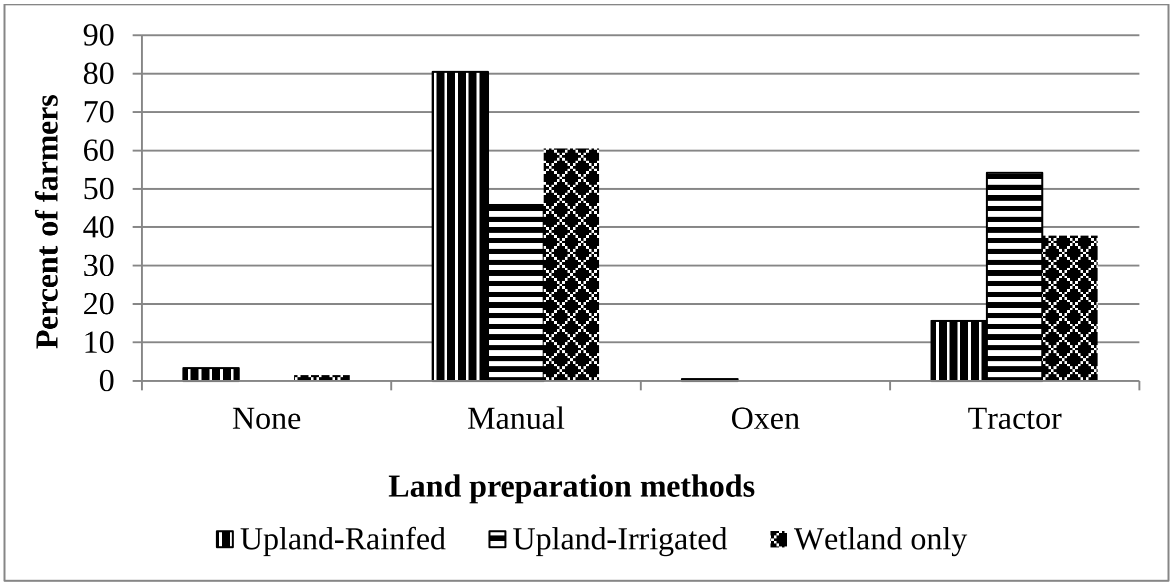

Figure 4. 3: Land preparation methods in maize production
Source: Author's survey data, 2017

Figure 4.3 shows that about 81% of maize farmers under the upland-rainfed system prepared their land using manual means. Similarly, the majority (61%) of the farmers under the wetland-only system prepared their maize farms manually. About 54% of maize farmers under the upland-irrigated system prepared their maize farms using tractors. Majority of maize farmers in the East African wetlands might have used manual means of land preparation due to small farms (see Table 4.2) and domestic labor availability within the households considering that most of them were not engaged in either informal or formal employment.

Figure 4.4 presents the findings of seed types used in maize production

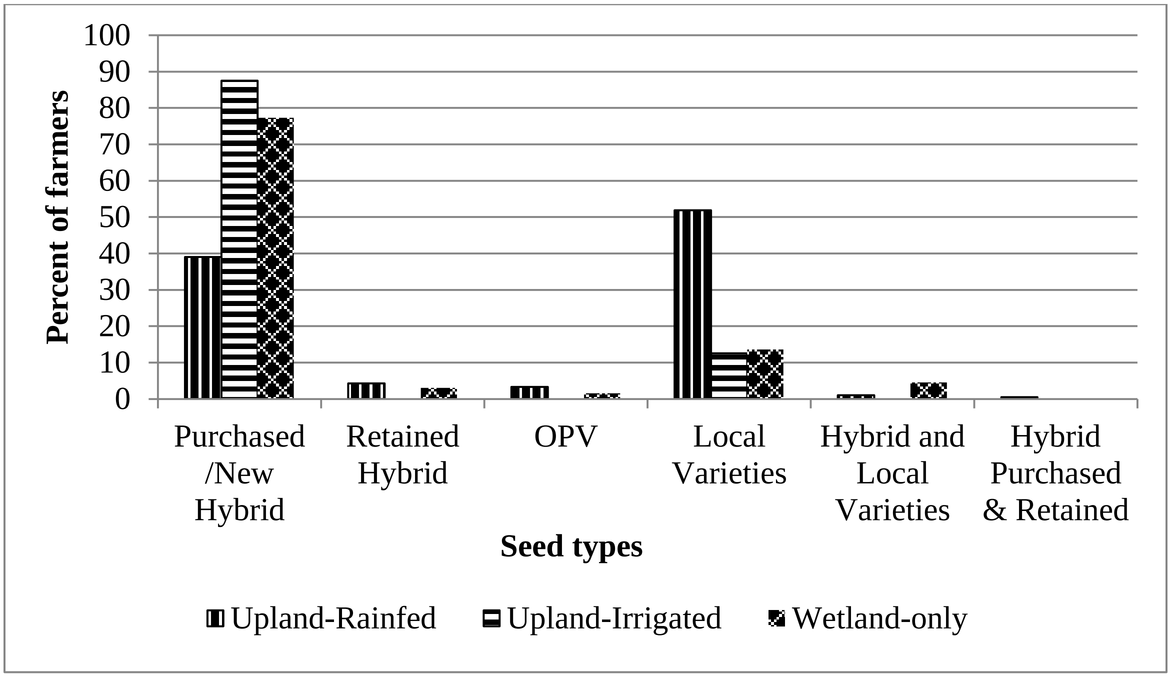

Figure 4. 4: Maize seed types
Source: Author's survey data, 2017

Figure 4.4 shows that the majority of maize farmers, comprising of 88% and 77% under the upland-irrigated and the wetland-only systems respectively, used purchased new hybrid seeds in maize production. Fifty-two percent of wetland maize farmers under the upland-rainfed system used local varieties. Low use of hybrid seeds under the latter system may have an adverse effect on maize productivity.

Table 4.5 presents the findings of different types of basal and topdressing fertilizers that maize farmers used in maize production.

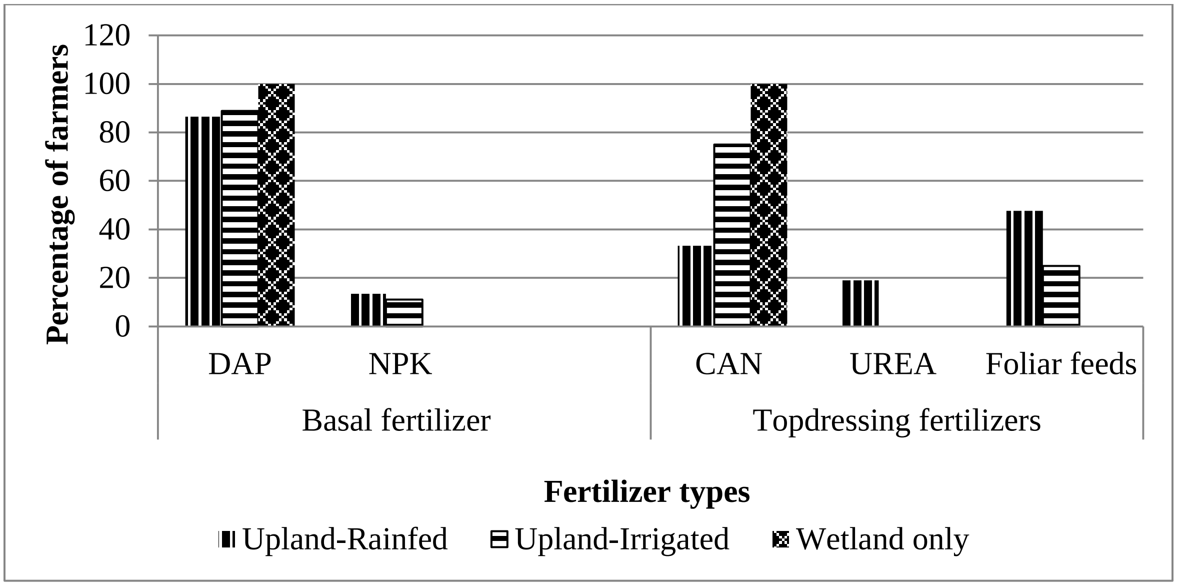

Figure 4. 5: Fertilizer types in maize production
Source: Author's survey data, 2017

Diammonium phosphate (DAP) had the highest use across all the systems as the basal fertilizer as shown in Figure 4.5. None of the maize farmers under the wetland-only system used Nitrogen, Phosphorus, and Potassium (NPK) during planting. All the maize farmers under the wetland-only system used Calcium Ammonium Nitrate (CAN) while 75% of the maize farmers under the upland-irrigated system used it for topdressing. Under the upland-rainfed system, the majority (48%) of the maize farmers used Urea for topdressing.

4.4.2 Agricultural Management Practices and Input Types among Rice Farmers

Figure 4.6 presents the findings of land preparation methods in rice production in Kilombero wetland.

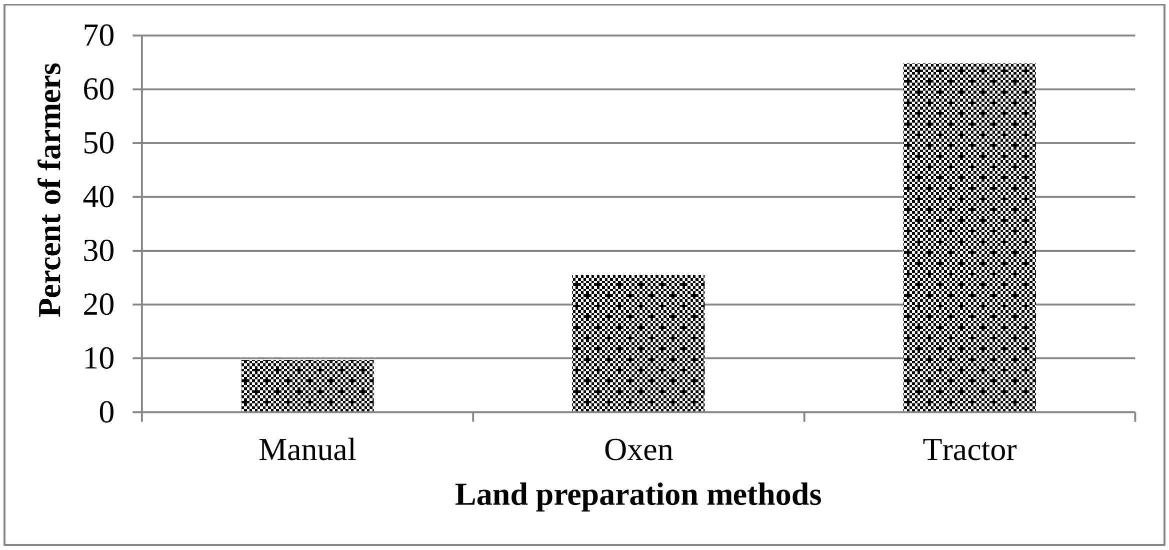

Figure 4. 6: Land preparation methods in rice production
Source: Author's survey data, 2017

The majority of rice farmers in the Kilombero wetland, comprising of 65 percent, used tractors as the main method of land preparation. The manual land preparation was the least used method in field preparation. It is important to note that using a tractor in land preparation reduces labor demand and drudgery, which will assist in reducing total production cost.

Figure 4.7 shows different types of rice seeds that were used during rice production in Kilombero.

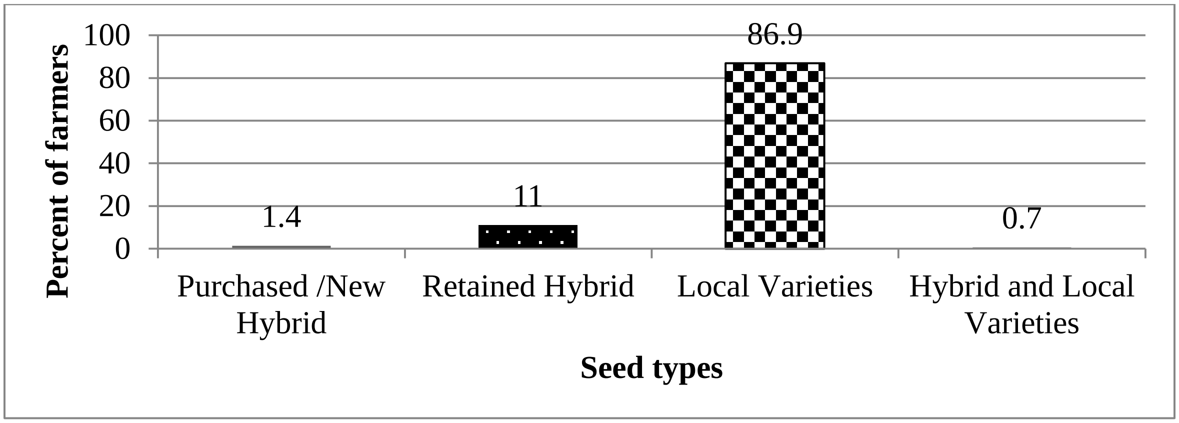

Figure 4. 7: Rice seed types
Source: Author's survey data, 2017

Figure 4.7 shows that about 87% of rice farmers used local seed varieties while about 1% used purchased hybrid seeds.

Figure 4.8 presents the findings of different basal and topdressing fertilizers used in rice production.

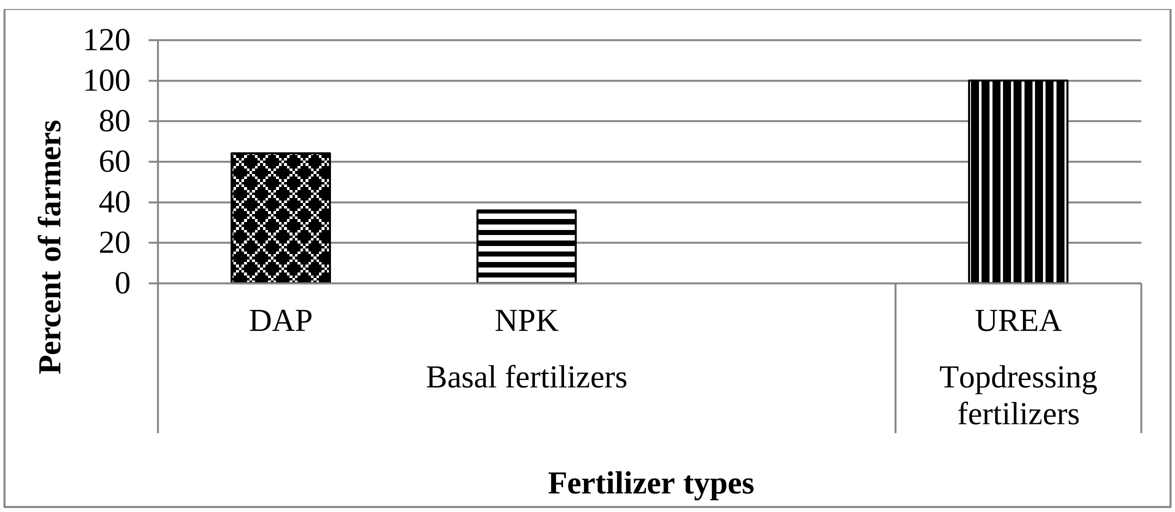

Figure 4. 8: Fertilizer types in rice production
Source: Author's survey data, 2017

Figure 4.8 shows that DAP and Urea were the major basal and topdressing fertilizers respectively. About 64% of rice farmers used DAP during planting while they all used Urea for topdressing. Rice producers from Kilombero wetlands acquire fertilizers from the Kilombero Plantations Limited (KPL), which determines the types of fertilizers available for rice production.

4.4.3 Inputs Use among Maize Farmers

Table 4.2 presents the quantities of inputs used in maize production among the maize farmers in East African wetlands under different agricultural land-use management systems.

Table 4. 2: Mean inputs used in maize production in East African wetlands

	Pooled (n=300)	Upland-Rainfed (n=210)	Upland-Irrigated (n=24)	Wetland-only (n=66)	F-value
Inputs	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	
Seeds (Kg ha^{-1})	18.38(7.59)	18.52(7.6)	17.68 (7.5)	18.2 (7.71)	0.158
Basal fertilizers (Kg ha^{-1})	65.07 (46.13)	63.13 (6.29)	65.48 (47.91)	71.11 (45.17)	0.751
Topdressing fertilizers (Kg ha^{-1})	47.13 (45.67)	43.93 (44.17)	56.34 (54.11)	53.98 (46.63)	1.755
Labor (Man-days ha^{-1})	55.32 (34.6)	56.17 (34.34)	37.9 (35.46)	58.93 (33.81)	3.522**
Manure (Kg ha^{-1})	2289.85 (2605.33)	2265.49 (2728.42)	2521.9 (2387.14)	2282.99 (2291.13)	0.104
Pesticides (Litres ha^{-1})	5.33 (4.05)	5.97 (3.76)	3.99 (4.09)	3.79 (4.43)	9.125***
Herbicides (Litres ha^{-1})	4.40 (2.96)	4.88 (2.76)	3.1 (3.25)	3.36 (3.1)	9.565***
Area under maize (Ha ha^{-1})	0.59 (0.71)	0.67 (0.8)	0.31 (0.27)	0.43 (0.43)	5.17***

****, *** statistic is significant at 5% and 1% respectively**
Source: Author's survey data, 2017

Seed quantities used in maize production were about 18 kg ha^{-1} and the findings show no significant difference across the different systems. The Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) recommends a rate of 25 kg ha^{-1} (Asea *et al*., 2014). As such, the lower seed rate across the systems may lower maize productivity.

Basal and topdressing fertilizer quantities used in maize production did not differ significantly across the different systems (see Appendix 6). Both basal and topdressing fertilizer application rates under upland-rainfed system were lowest, averaging at about 63 kg ha^{-1} and 44 kg ha^{-1} respectively. The highest basal fertilizer application rate was under the wetland-only system, averaging at about 71 kg ha^{-1}, while the highest topdressing fertilizer rate was under the upland-irrigated system, which averaged at about 56 kg ha^{-1}.

Labor used differed significantly across the systems. The number of man-days used under the wetland-only system was about 59 man-days ha^{-1}, which was significantly higher than labor used under the upland-rainfed and upland-irrigated systems, which averaged at about 56 and 38 man-days ha^{-1} respectively. This may be due to the fact that wetlands require the creation and maintenance of canals (Department of Ecology - State of Washington, 2010; Verhoeven & Setter, 2010).

Table 4.2 shows that manure quantity was highest under the upland-irrigated system with an average of about 2522 kg ha^{-1} while the lowest quantity was used under the upland-rainfed system, averaging at 2265 kg ha^{-1}. The quantities did not significantly differ across the systems.

The quantities of pesticides and herbicides used significantly differed across the land-use systems. The highest quantities of pesticides and herbicides used were under the upland-rainfed system and they averaged at about 5 and 4 litres per hectare respectively. The lowest pesticide quantities were used under the wetland-only system with an average of about 4 litres per hectare while herbicides were least used under the upland-irrigated system with an average of 3 litres per hectare.

Yield differed significantly across the systems with farmers under the upland-irrigated system having the highest quantity averaging at approximately 1373 kg ha^{-1} as shown in Figure 4.9. The least yield quantity was under the upland-rainfed system perhaps due to crops suffering from water stress, especially during the dry season. Also, maize yield was lower than the national average of about 1800 kg ha^{-1} and 1500 kg ha^{-1} in Kenya and Uganda respectively (Schroeder *et al*., 2013; Okoboi *et al*., 2012).

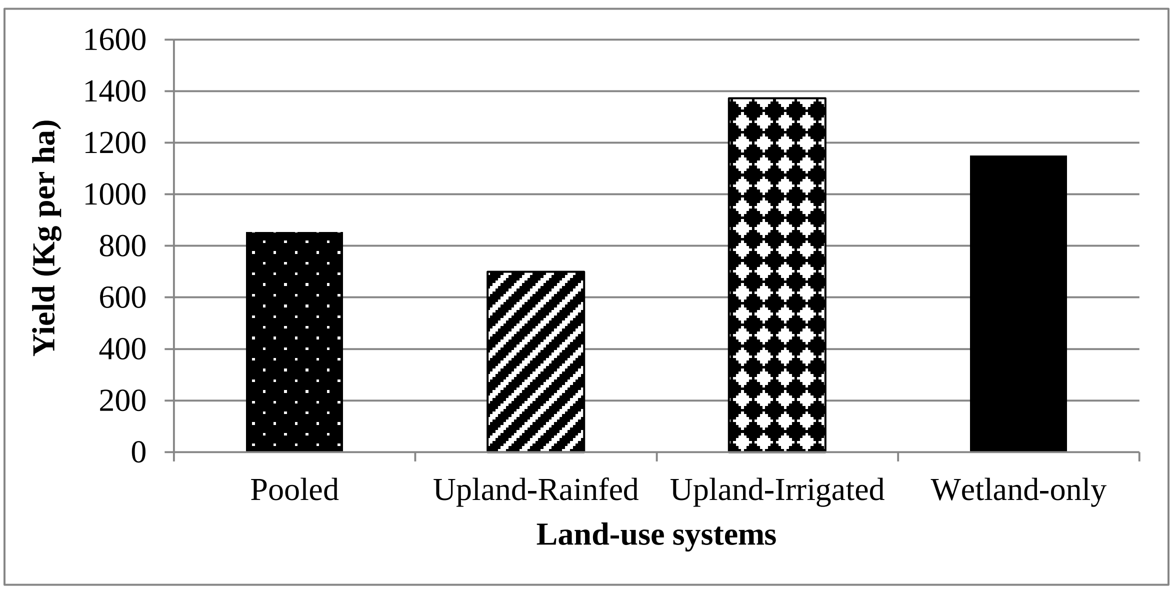

Figure 4. 9: Maize yield
Source: Author's survey data, 2017

4.4.4 Inputs Use among Rice Farmers

Table 4.3 presents the results for inputs used among rice farmers in the East African wetlands.

Table 4. 3: Input use among rice farmers

Input	Mean	Std. Dev	Min	Max
Seeds (Kg ha^{-1})	61.27	28.84	9.38	185.25
Basal fertilizer (Kg ha^{-1})	76.36	95.49	0.25	625
Topdressing fertilizer (Kg ha^{-1})	85.22	115.61	0.25	834.86
Labor (Man-days ha^{-1})	53.05	46.81	0.49	275.9
Pesticides (Litres ha^{-1})	3.25	3.28	0.12	24.7
Herbicides (Litres ha^{-1})	2.3	1.33	0.12	7.41
Area under rice (Ha ha^{-1})	1.69	1.9	0.2	16

Source: Author's survey data, 2017

Seeds quantity was about 61 kg ha^{-1} among the wetland rice farmers and the rate concurs with the recommended seed rate of 60-80 kg ha^{-1} in Tanzania (Global Yield Gap, 2013; the United Republic of Tanzania, 2007; Wilson & Lewis, 2015). The basal fertilizers quantities were lower according to the recommended rates of 123.5 - 130 kg ha^{-1} in Tanzania (IRRI, 2012; the United Republic of Tanzania, 2007). Similarly, the topdressing fertilizers quantities were also lower compared to the recommended rate of 87- 260 kg ha^{-1} (Africa Rice Center (WARDA), 2008). The number of man-days (53) used in the wetland rice production was smaller compared with the findings of Oumarou & Huiqiu (2016) and Kadiri *et al*. (2014) in South-western Niger and Niger Delta of Nigeria respectively, where the respective number of man-days used in rice production averaged at 162 and 180 man-days ha^{-1}. Mechanization of rice production in Kilombero wetland, especially during the planting period, might have contributed to the reduced labor demand as about 65% of the rice farmers used tractors for land preparation. Moreover, rice yield (1054 kg ha^{-1}) was below the national average of about 1.6-2.4 t ha^{-1} (Ngailo *et al*., 2016; Wilson & Lewis, 2015).

4.5 Group Membership and Institutional Factors among Rice and Maize Farmers in East African Wetlands

4.5.1 Group Membership and Institutional Factors among Maize Farmers

Figure 4.10 presents the results for the farmers that participated in organized groups.

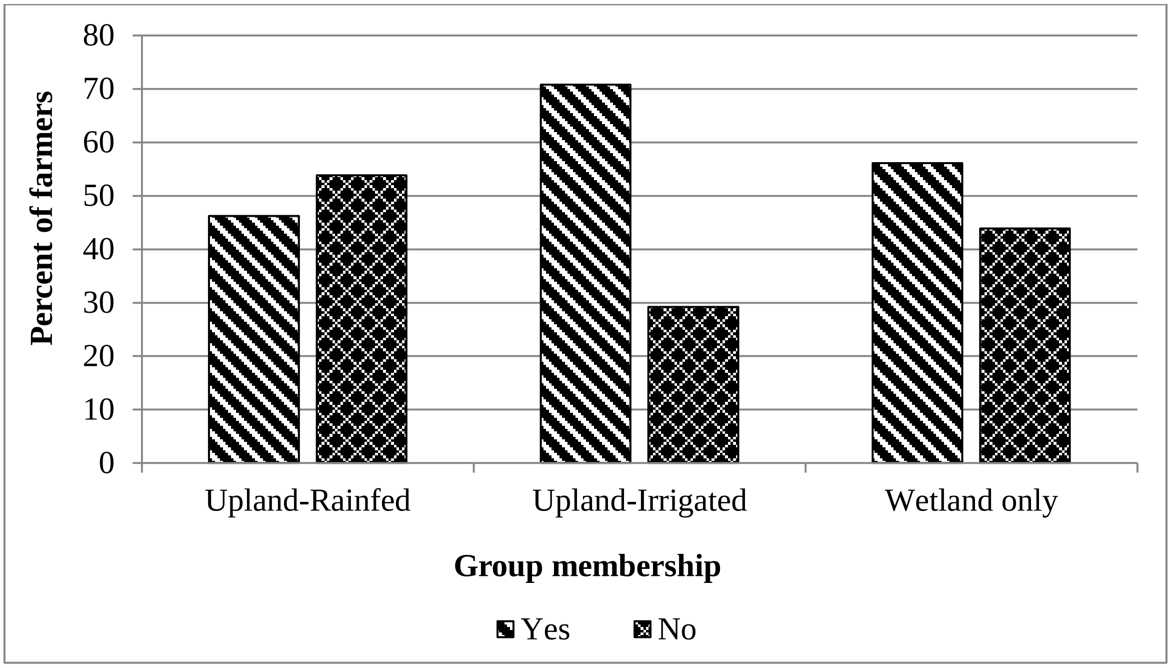

Figure 4. 10: Group membership among maize farmers
Source: Author's survey data, 2017

Majority of the farmers under the upland-irrigated and the wetland-only systems participated in organized groups. On the other hand, about 54% of upland-rainfed maize farmers did not belong to organized groups. Group membership has been known to positively influence productive efficiency through the benefits they gain from organized groups.

The farmers who belonged to organized groups benefited from several group activities as shown in Figure 4.11.

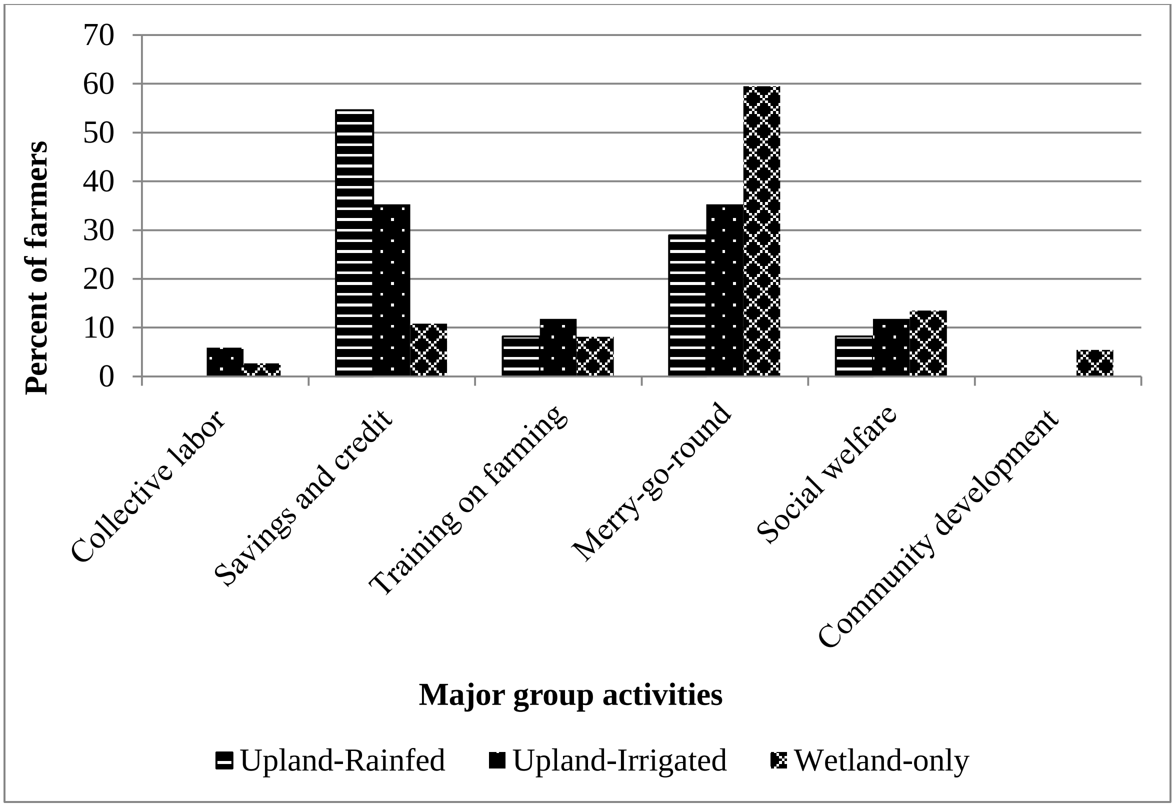

Figure 4. 11: Major maize farmer group activities
Source: Author's survey data, 2017

Under the upland-rainfed system, about 55% of those who belonged to organized groups utilized them for savings and credit services. This means that such farmers may have an increased affordability of yield-enhancing inputs. On the other hand, the *merry-go-round* was the major group activity among the upland-irrigated and the wetland-only rice farmers. Such farmers may use the money from the *merry-go-round* to purchase agricultural inputs such as seeds and fertilizers. Some maize farmers benefited from the groups through training on farming activities, collective labor, social welfare, and community development.

Table 4.4 shows the number of kilometers that maize farmers had to travel to access the extension service providers and the product markets.

Table 4. 4: Institutional factors among maize farmers

	Upland-Rainfed	Upland-Irrigated	Wetland-only	
Institutional factors	Mean (SD)	Mean (SD)	Mean (SD)	F-value
Distance to the private/public extension services provider	9.07 (6.45)	7.42 (5.74)	6.7 (5.87)	1.519
Distance of product market	1.14 (0.9)	1.79 (2.89)	1.17(0.68)	3.482**

** **Statistic is significant at 5% level**
Source: Author's survey data, 2017

The rice producers from the upland-irrigated system traveled significantly longer distances to the market compared to the farmers from the upland-rainfed and the wetland-only systems.

Figure 4.12 shows the percentage of maize farmers who accessed credit. (Mutambara, 2016)

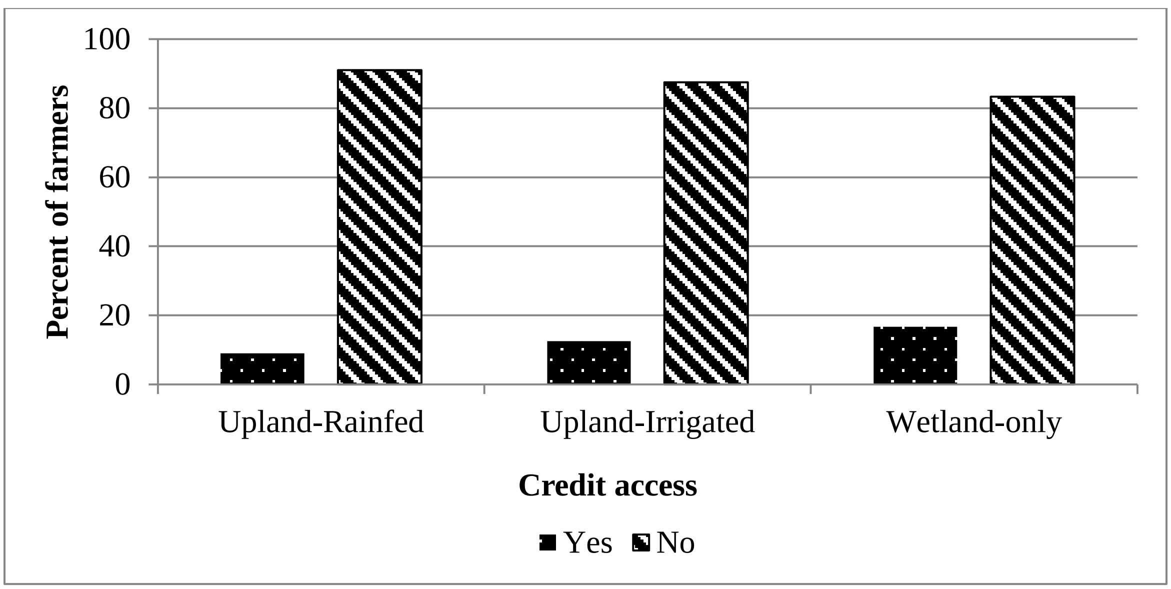

Figure 4. 12: Credit access among maize farmers
Source: Author's survey data, 2017

The majority of maize farmers did not borrow money for agricultural use. The least (9%) number of farmers who accessed credit was under the upland-rainfed system while the highest (17%) was under the wetland-only system.

4.5.2 Group Membership and Institutional Factors among Rice Farmers

Figure 4.13 presents the percentage of rice farmers who belonged to organized groups.

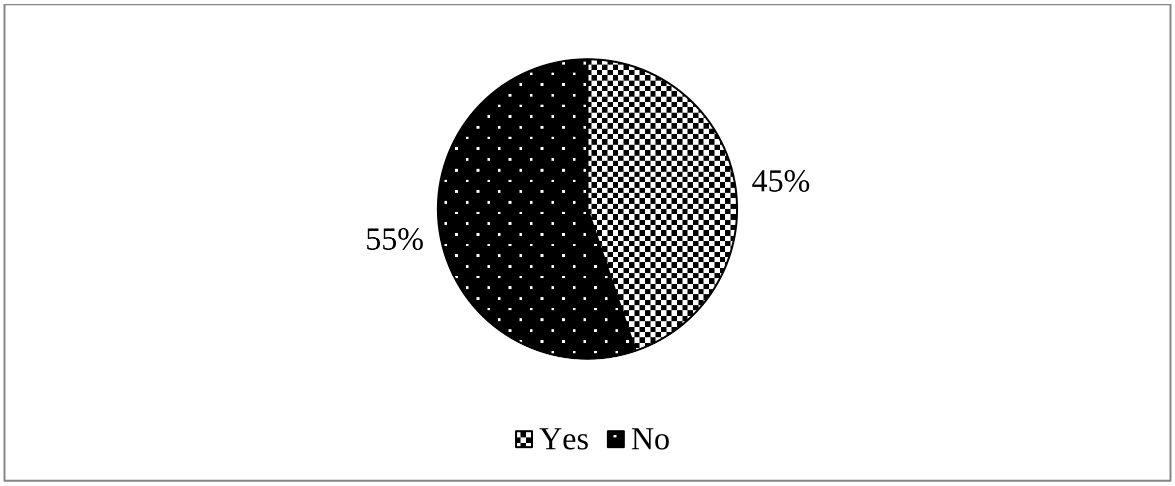

Figure 4. 13: Group membership among rice farmers
Source: Author's survey data, 2017

The majority (55%) of rice farmers did not belong to organized groups. Consequently, this may have adverse effects on rice productivity.

Rice farmers who belonged to organized groups participated in different activities as shown in Figure 4.14.

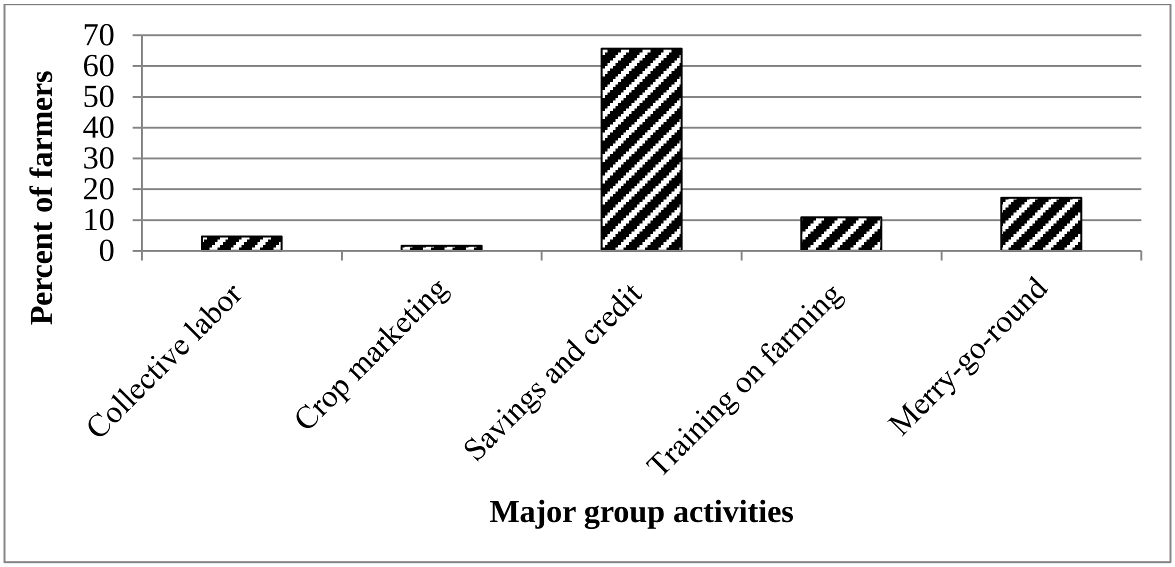

Figure 4. 14: Major rice farmer group activities
Source: Author's survey data, 2017

The majority (67%) benefited from the groups through savings and credit services (formal institutions). This implies that they had an increased capacity to acquire yield-enhancing inputs and technologies. About 17% obtained money by engaging in groups whose major activity was a *merry-go-round* (informal institutions).

The majority (65%) of rice farmers within the wetlands did not access credits for agricultural use as shown in Figure 4.15.

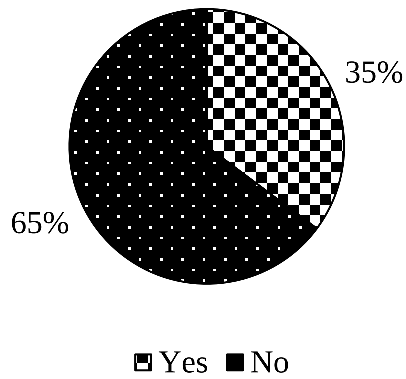

Figure 4. 15: Credit access among rice farmers
Source: Author's survey data, 2017

Table 4.5 shows the distances that farmers had to travel to access the extension services and product markets.

Table 4. 5: Institutional factors among rice farmers

Institutional factors	Mean	Std. Dev	Min	Max
Distance to the private/public extension services provider	3.52	5.64	0	34
Distance to product market	2.72	9.82	0	70

Source: Author's survey data, 2017

They traveled for an average of about 3.5 Km to access the nearest private or public extension services provider and about 2.7 Km to sell their produce.

4.6 Empirical Model Results

4.6.1 Validation Tests Results

Validation tests were done for stochastic frontier analysis models. The results of the multicollinearity tests reveal that the individual and mean VIF values were all less than 10 (see Appendix 3). This is an indication that multicollinearity was not a problem among the explanatory variables. Secondly, the results for the *Breusch-Pagan / Cook-Weisberg* tests for heteroscedasticity showed that the chi^2 values were insignificant (p>0.05) (see Appendix 4). The null hypotheses stating that the variables were homoscedastic were not rejected. Lastly, the results for *Ramsey* tests assisted in the failure to reject the null hypotheses that the models had no omitted variables since the F values were insignificant (p>0.05) (see Appendix 5).

4.6.2 Determinants of Maize Output in East African Wetlands

The results of the stochastic frontier production function (see equation 3.9) that was estimated to determine the factors affecting maize productivity in East African wetlands are presented in Table 4.6.

Table 4. 6: Stochastic frontier production function results for maize production in East African wetlands

Variable	Coefficient	Std. Error	P-value
Maize output (kg ha^{-1})			
Land (ha)	-0.023	0.078	0.765
Seed (kg ha^{-1})	0.306^{***}	0.092	0.001
Basal fertilizer (kg ha^{-1})	-0.001	0.078	0.988
Manure (kg ha^{-1})	0.191^{***}	0.063	0.002
Pesticide (litre ha^{-1})	0.156^{*}	0.094	0.098
Herbicide (litre ha^{-1})	0.072	0.260	0.782
Labor (man-days ha^{-1})	0.066	0.050	0.189
Topdressing fertilizer (kg ha^{-1})	0.082	0.075	0.274
_cons	4.684^{***}	0.575	0.000
sigma_v (σ_v)	0.598	0.063	
sigma_u (σ_μ)	1.53	0.111	
lambda (λ)	2.558	0.153	
gamma (γ)	0.867	0.358	
Likelihood-ratio test of σ_μ=0:	$Chibar^2(01) = 31.98$	$Prob>=chibar^2 = 0.000$	
Log likelihood = -444.61	Wald chi2(8) = 44.60	$Prob > chi^2 = 0.0000$	

*, **, *** statistic is significant at 10%, 5% and 1% level respectively

The estimated model had a log likelihood value of -444.61 and a Wald chi^2 of 44.6, which was strongly significant at 1% level. This shows that the model was correctly specified and that the explanatory variables were collectively able to explain the variations in maize output as explained in the studies done by Ingabire (2014) and Sibiko (2012). The value of lambda (λ) was approximately 2.6 and according to Lema *et al*. (2016), a value greater than one indicates that the one-sided error term (μ) dominates the random error (v). This means that most of the variations in maize output emanated from farmers' practices as opposed to random variability. Indeed, the value of gamma (γ) was 0.867, which shows that 86.7% of variations of maize output from the frontier were attributed to farmers' technical inefficiencies.

Seeds had the biggest positive elasticity (0.306), which was strongly significant at 1% level. This implies that 1% increase in seed quantity significantly increased maize output by 0.31%. Ahmed *et al*. (2015) and Kibirige, (2008) also found that seed rate was a positive determinant of output on maize farming in Central Ethiopia and Masindi district of Uganda respectively. The fact that elasticity from seed was the highest may also imply that seed quantity used was the most limiting factor to maize production, which constrained farmers from attaining maximum productivity. This may be due to the low seed rate of about 18 kg ha^{-1} within the wetlands compared to the recommended rate of 25 kg ha^{-1} (Asea *et al*., 2014).

Manure influenced maize output at 1% significance level and the elasticity was 0.191. As such, 1% increase in manure quantity in maize production significantly increased maize output by 0.19%. According to Mugwe *et al*. (2009), manure is important for an increase in maize output and soil conservation and as such, an increase of manure use is critical for wetland sustainability. This is perhaps because; manure ensures availability of Nitrogen for the successive crop (Mafongoya & Jiri, 2016). This may reduce manure demand in maize production and consequently, soil pH in the wetlands lowers at a reduced rate.

Pesticides influenced maize output at 10% significance level and the elasticity was 0.156. This implies that 1% increase in pesticide quantity led to 0.16% increase in maize output within the wetlands. In a study of the technical efficiency of maize production in Swaziland, Dlamini *et al*. (2012) found that pesticides were influencing output at 5% level. Pest invasion in this regard could significantly compromise maize productivity if farmers did not apply the pesticides within the wetlands.

Land, although insignificant, emerged as a negative determinant of maize output, which was against the positive expectation. The findings also contradict with those of Kibirige (2014). This implies that land may have been overused and more expansion led to a decrease in the increase of marginal output. Other insignificant determinants of productivity included the basal fertilizers, labor, and herbicides.

4.6.3 Determinants of Rice Output in East African Wetlands

The SFA model estimation results are presented in Table 4.7.

Table 4. 7: Stochastic frontier production function results for rice production in East African wetlands

Variable	Coefficient	Std. Error	P-value
Rice output (kg ha^{-1})			
Land (ha)	0.448***	0.056	0.000
Seed (kg ha^{-1})	-0.015	0.075	0.839
Basal fertilizer (kg ha^{-1})	0.226***	0.039	0.000
Pesticide (litre ha^{-1})	0.029	0.023	0.211
Herbicide (litre ha^{-1})	-0.034	0.036	0.340
Labor (man-days ha^{-1})	-0.051	0.063	0.419
Topdressing fertilizer (kg ha^{-1})	0.083**	0.035	0.016
_cons	6.789***	0.378	0.000
sigma_v (σ_v)	0.058	0.035	
sigma_u (σ_μ)	0.979	0.065	
lambda (λ)	16.75	0.083	
gamma (γ)	0.803	0.081	
Likelihood-ratio test of σ_μ=0:	Chibar^2(01) = 51.01	Prob>=chibar^2 = 0.000	
Log likelihood = -108.336	Wald chi^2(8) = 194.72	Prob > chi^2 = 0.0000	

****, *** statistic is significant at 5% and 1% level respectively**

The findings show that the likelihood-ratio test (σ_μ=0) had a Chibar^2 of 51.01, which was statistically significant at 1% level. It is evident that inefficiency effects are significantly different from zero and therefore rice farmers in East African wetlands do not operate on the production frontier. Also, the value of gamma (γ) (0.803) shows that 80.3% of variations in rice output from the frontier are within the farmers' control. The value of lambda (16.75) reveals the domination of one-sided inefficiency component (σ_μ) over measurement errors and other factors that are beyond farmers' control (σ_v).

As expected (see Table 3.1), the land used was a positive determinant of rice output within the wetlands. It influenced output at 1% significance level and the coefficient was 0.445 implying that 1% increase in farm size under rice farming would increase rice output by 0.45%. Kadiri *et al*. (2014) and Islam & Kalita (2016) also found that land was influencing paddy rice output at 1% level in Niger Delta region of Nigeria and West Garo district of Meghalaya state, India respectively. In the Kilombero wetland, it means that rice farmers have room to expand their output as they have only utilized 32% of the total farm sizes. It also suggests that initiatives such as the SAGCOT project's Kilombero cluster will implement the expansion of rice production in Kilombero wetland sustainably because the wetland is not overused.

Both basal and topdressing fertilizers strongly influenced rice output at 1% level. Kadiri *et al*. (2014) and Oumarou & Huiqiu (2016) also found that fertilizer significantly influenced rice production in Niger Delta and Southwestern Niger regions of Nigeria at 1% level respectively. There is room to attain maximum rice productivity by increasing fertilizer use because 1% increase in basal and topdressing fertilizers will increase rice output by 0.23% and 0.1% respectively. Within the wetlands, the basal fertilizer was not optimally used as rice farmers used about 76 kg ha^{-1} compared to the recommended rates of 123.5 - 130 kg ha^{-1} in Tanzania (IRRI, 2012; United Republic of Tanzania, 2007). Similarly, the topdressing fertilizer was not optimally used because farmers used about 85 kg ha^{-1} compared to the recommended rate of 87-260 kg ha^{-1} (Africa Rice Center (WARDA), 2008). Addressing the use of fertilizer to the optimal levels can help in increasing rice output on wetland farms while decreasing the threat of wetland existence due to rampant encroachment. The government should closely monitor the use of inorganic fertilizers or train farmers on the use of organic fertilizers because inorganic fertilizers have several adverse effects on the wetland soils, water, fauna, and flora. One of the effects includes the rapid growth of algae among other weeds that may deplete oxygen in the water. There is also contamination of water from chemical leaching in the soils whereby human and livestock lives are at risk of ingesting contaminated food materials (Rwanda Environment Management Authority, 2014; Wiederholt & Johnson, 2005).

The insignificant determinants of rice productivity included labor, pesticides, herbicides, and seed. The coefficient of seed variable, although insignificant was negative, which contradicted with the findings of Wakili and Isa (2015). It shows that the seed rate had a potential of overuse.

4.6.3 Farm-specific Productive efficiency among Maize and Rice Farmers in East African Wetlands

4.6.3.1 Productive Efficiency among Maize Farmers in East African Wetlands

After generating the elasticities, the farm-specific efficiency scores were obtained using Frontier 4.1c version as developed by Coelli *et al*. (2005). The results presented in Table 4.8 were prepared with the aid of SPSS v23, where the differences in means of productive efficiency among maize farmers from the different land-use systems were analyzed using One-way ANOVA. In order to obtain the economic efficiency, the cost function was first run and farm-specific cost efficiencies were generated. Economic efficiency was then generated as the inverse of cost efficiency scores. From EE and TE scores, AE was obtained as the quotient of EE/TE (Kolawole, 2007).

Table 4. 8: Productive efficiency among maize farmers under different land-use systems in East African wetlands

Efficiency		Upland-rainfed	Upland-irrigated	Wetland-only	F-stat	P-value
TE	Mean	0.38	0.52	0.49	8.147***	0.000
	Std. Deviation	0.22	0.23	0.25		
	Min	0.01	0.13	0.03		
	Max	0.9	0.93	0.93		
AE	Mean	0.51	0.56	0.59	4.541**	0.011
	Std. Deviation	0.19	0.16	0.18		
	Min	0.02	0.2	0.15		
	Max	0.95	0.86	0.96		
EE	Mean	0.34	0.31	0.35	0.406	0.667
	Std. Deviation	0.2	0.15	0.19		
	Min	0.02	0.06	0.04		
	Max	0.81	0.63	0.84		

****, *** statistic is significant at 5% and 1% level respectively**
Source: Author's survey data, 2017

Maize farmers from the upland-irrigated system were the most technically efficient with a mean TE of 52%. The findings show that there was a significant difference in mean TE among maize farmers under different systems (F=8.147, p<0.001). The *LSD Post-hoc* tests reveal that farmers who produced maize under the upland-rainfed system had a significantly lower TE as compared to if they produced under either upland-irrigated or wetland-only systems at 1% level (see Appendix 9). There is no significant difference in the mean TE among maize farmers who produced under either upland-irrigated or wetland-only systems (p=653). This implies that, for maize farmers to boost their technical efficiency, they should consider producing under the upland-irrigated system while considering the use of more manure, pesticides, and seeds, which were the significant determinants of productivity. Farmers under the upland-rainfed system had the lowest mean TE of 38%. The highest maize production frontier (93%) was from both the upland-irrigated and the wetland-only systems. For a maize farmer with an average TE of

38% to achieve the TE level of the most technically efficient (93%) farmer, he/she would realize proportional inputs saving of 59.14% as given by [(1-(38/93)) x 100].

The highest mean AE was under the wetland-only system at 59%. One-way ANOVA results reveal that there was a statistically significant difference in mean AE among maize farmers who produced under different agricultural land-use systems at 5% level (F=4.541, p=0.011). The *LSD Post-hoc* tests reveal that maize farmers from the wetland-only had significantly higher mean AE than maize farmers who produced under the upland rainfed. No significant difference in mean AE existed among farmers who produced maize under either the upland-irrigated or the wetland-only system. The least mean AE was under the upland-rainfed system with 51% efficiency while the most allocative efficient farmer produced under the wetland-only system with 96% AE. A farmer with an average mean AE (51%) can realize a total cost-saving of 46.88% as given by [(1-(51/96)) x 100] to achieve the AE of the most allocative efficient farmer with 96% AE. This also means reduced wastage of production resources in wetland maize production.

Economic efficiency did not significantly differ among farmers under the different land-use system. Maize farmers under the upland-irrigated system had the least mean EE of 31%. The farmer who exhibited the highest EE originated from the wetland-only system. There is a possibility of a total production cost saving of up to 63.1% as given by [(1-(31/84)) x 100], for the maize farmer with a mean EE of 31% to attain 84% EE. This translates to increased wetland maize production profitability.

The results of TE, AE, and EE distribution among maize farmers are presented in Appendix 7. The majority (50%) percent of farmers under the upland-irrigated system had

TE ranging from 50% to 74%. Similarly, 54.2% of the farmers attained AE ranging from 50% to 74 percent. The Economic efficiency class, 25-49%, had the majority of farmers (50%).

4.6.3.2 Productive efficiency among Rice Farmers East African Wetlands

The results for productive efficiency among the rice farmers are presented in Table 4.9 and show the mean TE, AE, and EE.

Table 4. 9: Productive efficiency among rice farmers in East African wetlands

Efficiency	Mean	Standard Deviation	Minimum	Maximum
TE	0.59	0.21	0.09	0.94
AE	0.72	0.22	0.12	0.95
EE	0.46	0.23	0.07	0.94

Source: Author's survey data, 2017

Realization of maximum EE in rice production was more constrained by technical inefficiency than allocative inefficiency among wetland rice farmers. This is because; they operated at 41% technical inefficiency and 28% allocative inefficiency. A rice farmer with a mean TE (59%) would reduce inputs proportionally up to 37.23% as given by [(1-(59/94)) x 100], to operate on the wetland's best frontier of 94% TE. A farmer with the mean AE of 72% can realize a total production cost saving of 24.21% to attain the efficiency of the most efficient farmer (95%). In addition, a total production cost saving of 51.06% would be realized for a farmer with the mean EE of 46% to attain the efficiency of the most efficient farmer (94%) while maximizing rice productivity and profitability. The majority (40.7%) of rice farmers attained TE levels of 50-70%. The class, 75-100%, had the most allocative efficient farmers while 35.2% attained EE between 25 to 49%. The distributions of TE, AE, and EE are presented in Appendix 8.

4.6.4 Determinants of Maize and Rice Production TE, AE, and EE in East African Wetlands

4.6.4.1 Determinants of TE, AE, and EE in Maize Production in East African Wetlands

Table 4.10 presents the Tobit estimation results of the Equation (3.14) on the determinants of TE, AE, and EE in Maize Production in East African Wetlands.

Table 4. 10: Tobit regression estimates of factors influencing maize productive efficiency in East African wetlands

	TE		AE		EE	
Variable	**Coeff.**	**Std. Error**	**Coeff.**	**Std. Error**	**Coeff.**	**Std. Error**
Age	-0.001	0.001	-0.001	0.001	-0.001	0.001
Household size	-0.007	0.005	0.011**	0.005	0.003	0.004
Education	0.006*	0.002	0.004	0.002	0.004*	0.002
Farming years	0.002*	0.001	0.001	0.001	0.001	0.001
Distance to Mkt. (Km)	-0.007***	0.001	-0.003*	0.001	-0.003*	0.001
Extension Edu. (Km)	-0.010***	0.002	0.001	0.002	-0.003**	0.001
Off-farm income	0.001	0.001	0.001	0.001	0.001	0.001
Upland-rainfed	-0.062*	0.035	-0.048	0.031	-0.013	0.032
Upland-irrigated	-0.010	0.051	-0.056	0.045	-0.033	0.047
Gender (F=1)	-0.096***	0.030	-0.010	0.026	0.045	0.027
Group membership	0.016	0.025	0.07***	0.022	0.044*	0.023
Credit access	0.089**	0.042	0.033	0.037	0.019	0.038
Wetland location	-0.024	0.033	-0.093***	0.029	0.022	0.030
_cons	0.632***	0.070	0.610***	0.062	0.398***	0.064
Log-likelihood	49.46		81.56		75.24	
LR $chi^2(13)$	91.25		42.84		18.98	
Prob > chi^2	0.000		0.000		0.012	

***, **, *** statistic is significant at 10%, 5% and 1% level respectively**

Education of the farmer had a positive influence on both TE and EE at 10% significance level. The findings show that an extra year in formal schooling increased farmers' TE and EE by 0.6% and 0.4% respectively. Ahmed *et al*. (2015), Mutoko *et al*. (2015), and Okoye *et al*. (2016) reported that education had a positive influence on the aforementioned efficiency. Ahmed *et al*. (2015) explained that educated farmers have an improved ability to interpret and utilize information about markets. Also, Nyagaka *et al*. (2010) and Kibirige, (2014) explained that farmers with more formal education are likely to adopt new technologies such as fertilizers and improved planting materials better than the less formally educated farmers, which improves their productivity. Within the Ewaso Narok and Namulonge wetlands, maize farmers had acquired at least seven years of primary education and therefore an increase in formal education would further increase their productivity and profitability.

Maize farming experience within the wetlands had a positive influence on TE at 10% significance level. An additional year spent on maize production gave farmers an opportunity to increase their TE by 0.2%. Dlamini *et al*. (2012) also found a positive influence in maize production in Swaziland. Oumarou & Huiqiu (2016) explained that farmers who have planted a certain crop for a long time are able to predict accurately on when to plant, the appropriate cropping materials, and types and amounts of inputs to use in production. In these wetlands, experienced maize farmers understand wetland soil and water conservation practices better than the inexperienced counterparts do and consequently maize production may be done throughout the year. This increases their productivity compared to their inexperienced counterparts.

Distance to output market had a negative influence on the three types of productive efficiency. Technical efficiency was significantly influenced at 1% level while the other two efficiencies were influenced at 10% level. An extra kilometer to output markets lowered farmers' TE by 0.7% and the other efficiencies (AE and EE) by 0.3% each. A negative influence of long distance to the market on efficiency was also reported by

Ahmed *et al*. (2015) and Mutoko *et al*. (2015). This is perhaps due to extra costs that the farmers would incur during transportation to access these markets. As a result, maize farmers within these wetlands may be discouraged to engage in market-driven production. Purchasing of yield-enhancing inputs such as fertilizer and improved seeds may also be limited by the non-market-driven production and this negatively influences TE of maize farmers.

Longer distances between wetland maize-farming households and agricultural extension education providers reduced farmers' TE and EE. An additional kilometer between maize-farming households and extension services providers lowered TE and EE indices by 1% and 0.3% respectively. This is especially when maize farms are located in the remote areas where feeder roads are impassable and thus it becomes difficult for the extension officers to make a substantial number of visits to farmers.

Upland-rainfed land-use system had a negative influence on farmers' TE. Since the base system in the *land-use* dummy variable was the wetland-only system, it was evident that maize farmers' TE under the upland-rainfed system was likely to be less than that of maize farmers under the wetland-only by 6%. This shows that there is a possibility of resource wastage (such as fertilizers and improved seeds) if maize farmers produce under the former system and especially when maize crops suffer from water stress. This may significantly increase maize farmers' technical inefficiency.

Gender negatively influenced TE at 1% level. From Table 4.10, women had 9.6% lower TE than men. A negative influence of gender on TE was also reported by Ngenoh *et al*. (2015) and Oumarou & Huiqiu (2016). In most cases, men are more educated than their female counterparts, and they own the land title deeds such that they are able to secure agricultural credits using them as collaterals (Ngenoh *et al*., 2015). This makes them more technically efficient than their female colleagues due to their increased advantage to access yield-enhancing inputs such as fertilizers and agrochemicals.

Access to agricultural credits was a significant positive determinant of TE at 5% level. Maize farmers who accessed agricultural credits had 8.9% higher TE than those who did not access. A significant positive influence was also reported by Karani-Gichimu *et al*. (2015), Ng'ombe & Kalinda (2015), and Wakili & Isa (2015). Ng'ombe & Kalinda (2015) explained that a properly used credit enhanced a more diversified farming system, which steadies, and possibly improve productivity due to increased affordability of yield-improving resources. Also, Karani-Gichimu *et al*. (2015) explained that farmers who borrow credit feel that they must work hard to produce maximum output in order to repay the debts and still make profits.

Group membership was a significant positive determinant of AE at 1% level. Wetland maize farmers who belonged to farmer groups were likely to have 7% higher AE than their counterparts who did not belong to any farmer group. Sanyang (2014) and Wakili & Isa (2015) reported a similar relationship between AE and group membership. Sanyang (2014) explained that farmers who belong to an organized group or an association usually have opportunities to access quick support from the government, NGOs, donors, and other stakeholders. These agencies enable prices and technologies information flow, subsidize inputs, offer financial and input credits to farmers, and organize for product markets among others. Thus, wetland farmers who participate in farmer groups are able to be more allocative efficient than their counterparts. Again, farmer groups offer agricultural training on the best production practices to their members and this improves their efficiency in the allocation of production resources.

Wetland's country of location had a significant negative influence on AE at 1% level. As such, wetland maize farmers in Uganda were likely to be 9.3% less allocative efficient than the Kenyan counterparts were. This shows that Kenyan wetland maize producers were able to allocate their production resources better than their Ugandan counterparts did. This is perhaps due to easily manageable smaller wetland farm sizes that Kenyan households owned compared to those in Uganda. It may also depend on the maize farming experience that Kenyan wetland farmers had, averaging at 15 years, compared to 8 years that Ugandan wetland farmers had. According to Oumarou & Huiqiu (2016), farmers who have planted a certain crop for a long time are able to predict accurately on when to plant, the appropriate cropping materials, as well as types and amounts of inputs to use in production.

Age and off-farm income were insignificant determinants of all types of productive efficiency. Despite the insignificant influence of age to efficiency, the coefficient had a negative sign, which was consistent with the findings of Nchare (2007). The author attributed the negative influence of age on efficiency to resistance to technology as farmers advance in age.

4.6.4.2 Determinants of TE, AE, and EE in Rice production in East African Wetlands

A Tobit model was run as specified earlier in Equation (3.15). The results are presented in Table 4.11, which shows the findings of the determinants of TE, AE, and EE in Rice production in East African Wetlands.

Table 4. 11: Tobit regression estimates of factors influencing rice productive efficiency in East African wetlands

	TE		AE		EE	
Variable	**Coeff.**	**Std. Error**	**Coeff.**	**Std. Error**	**Coeff.**	**Std. Error**
Age	-0.002	0.001	0.004	0.004	0.004	0.003
Household size	0.004*	0.002	0.009	0.010	0.01*	0.007
Education	0.015***	0.002	0.044***	0.010	0.005	0.007
Farming (yrs)	0.001	0.001	-0.004	0.005	-0.004	0.004
Distance to mkt. (km)	-0.001	0.001	-0.001	0.002	-0.001	0.002
Extension edu (km)	-0.002*	0.001	-0.004	0.004	-0.001	0.002
Off-farm income	0.002***	0.001	0.002**	0.001	0.002***	0.001
Gender (F=1)	-0.019	0.012	0.076**	0.049	0.051	0.035
Group membership	0.031**	0.013	0.081***	0.005	0.037	0.038
Credit access	0.017	0.011	0.062	0.046	0.042**	0.032
Wetland location	-0.003	0.009	0.039	0.040	0.017	0.028
_cons	0.357***	0.055	0.582***	0.222	0.154	0.156
Log-likelihood	219.27		17.85		68.33	
LR $chi^2(12)$	368.83		13.21		96.12	
Prob > chi^2	0.000		0.035		0.000	

***, **, *** statistic is significant at 10%, 5% and 1% level respectively**

Household size positively influenced rice farmers' TE and EE at 10% level. An additional member of the household increased TE and EE by 0.4% and 0.1% respectively. A positive influence was also reported by Aboki *et al*. (2013), Ayinde *et al*. (2015), and Girei *et al*. (2013). Ayinde *et al*. (2015) and Ahmed *et al*. (2015) explained that many farmers depend on household labor to increase production due to its availability, inexpensiveness, and ease of timely allocation in different farm activities especially during planting, weeding, and harvesting.

Formal education had a significant positive influence on TE and AE at 1% level. Farmers who acquired one more year on their formal education increased their TE and AE by 1.5% and 4.4% respectively. Such influence was reported by Akpan *et al*. (2013), Mburu *et al*. (2014), Mutoko *et al*. (2015), and Thabethe & Mungatana (2014). Thabethe

& Mungatana (2014) explained that farmers with formal education are able to acquire, analyze and comprehend important information about input mix and better production practices, which increases their ability to make timely decisions during production.

Technical efficiency of rice farmers was negatively influenced by longer distances to the extension service providers. An addition Kilometer reduced farmers TE by 0.2%. Extension contacts are reduced especially for farmers in places where road network might be poor thus making them impassable. Farmers may afford new production technologies but their technical efficiency may be compromised if they do not use them rightly. Asogwa *et al*. (2011) explained that having an extension officer within the area of production enables farmers to utilize the extension messages, which increases their productivity.

Off-farm income positively influenced both TE and EE at 1% level and AE at 5% level. Farmers who engaged in activities that earned them non-farm income had 0.2% improved productive efficiency. Malinga *et al*. (2015) and Wakili & Isa (2015) also found a positive influence between off-farm income and the two productive efficiency types. Islam *et al*. (2012) explained that farmers with off-farm income are likely to adopt new technologies such as improved seeds faster than their counterparts are. This is perhaps due to increased affordability of yield-enhancing inputs.

Gender significantly influenced AE at 5% level. This implies that female farmers were likely to have 7.6% higher AE than their male counterparts. Sanyang (2014) also found that female farmers were more allocative efficient than their male counterpart in rice production in the Gambia. The study argues that this is possible because, in a typical

African setting, women not only engage in the management of domestic affairs but also in some farming issues.

Group membership significantly influenced TE and AE at 5% and 1% levels respectively. Rice farmers who belonged to farmer groups within the wetland had 3.1% and 8.1% higher TE and AE respectively than their counterparts. Group membership has been found by other studies to positively influence both TE and EE (Sibiko, 2012; Mburu *et al*. 2014; Sanyang, 2014). Wetland rice farmers who belong to farmer groups or associations can access input credits, agricultural training, and linkage to product markets among others. This improves their productivity due to the proper and efficient allocation of resources (Sanyang, 2014).

Credit access positively influenced wetland rice farmers' EE at 5% level. Farmers who borrowed agricultural credit had 4.2% higher EE than those who did not acquire credit. Ahmed *et al*. (2015) and Haile (2015) also found credit access being a positive determinant of EE. Sibiko (2012) explained that farmers who borrow money for agricultural production afford the yield-improving inputs such as improved seeds and fertilizers, and labor-saving inputs such as herbicides. This increases their yield while reducing some production costs, which translates to increased productivity and profitability.

Insignificant factors that influenced productive efficiency include age, farming experience, and distance to the market. Age of the farmer was found by Nchare (2007) to be a significant determinant of productive efficiency at 36-50 years bracket. From Table 4.2, the mean age of rice producers was about 48 years, which was close to the upper limit of the age bracket where farmers are presumed to increase their efficiency. The influence of age on efficiency is therefore relatively weak.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR POLICY ACTION

5.1 Introduction

The chapter comprises a summary of the research, conclusions, and recommendations for policy action sections. All the conclusions are based on the findings for each objective. The recommendations for policy action are drawn from various gaps and weakness found in resource use as well as determinants of productive efficiency.

5.2 Summary

The study was titled *Technical, Economic and Allocative Efficiency among Maize and Rice Farmers under Different Land-Use Systems in East African Wetlands*. The background information showed that due to declining productivity among the major staples in East Africa, farmers have found their way into productive areas such as wetlands. As such, farmers engage in agricultural production within and around wetlands under different agricultural land-use management systems (ALUMSs). Farmers thus need to strike the balance between food production and wetlands sustainability; a balance that would be met by an improvement of productive efficiency. This begged for the questions; 1) Are farmers within and around East African wetlands producing efficiently? and 2) Which agricultural land-use management system (ALUMS) is associated with the highest productive efficiency? The objectives of this study were; 1) to identify the determinants of productivity, 2) to assess TE, AE, and EE under the different systems, and 3) to determine the factors influencing productive efficiency.

Data were collected from three study sites that were purposively selected based on their importance, risk of degradation, and geomorphic attributes. The study areas included Ewaso Narok wetlands (Kenya), Namulonge (Uganda), and Kilombero (Tanzania). A cross-sectional survey was used as the research design where a sample of 445 households was randomly selected using a semi-structured interview schedule.

The first objective was estimated using the SFA model of a Cobb-Douglas specification. The inputs that significantly influenced maize output were seeds, manure, and pesticides while those that influenced rice yield were land and fertilizers. The results revealed that most of the variations in maize yield emanated from farmers' practices as opposed to random variability. For instance, maize seed rate was significantly below the recommended planting rate while fertilizers were significantly below the recommended application rates in rice production.

The second objective was analyzed using Frontier 4.1c software to generate farm-specific efficiencies. In maize production, the highest mean TE was among farmers under the upland-irrigated system while those under the upland-rainfed had the least TE. Farmers under the wetland-only system had the highest AE while those under the upland-rainfed had the lowest mean AE. Maize producers under the wetland-only system had the highest mean EE. In rice production, the mean EE was the lowest compared to AE and TE.

The third objective was analyzed using a two-limit Tobit model due to the nature of the dependent variable. In maize production, distance to the product market and to the extension service provider, formal education, household size, farming experience, upland-rainfed system, and gender were the major factors affecting TE. The AE was majorly influenced by group membership and the wetland's country of location. EE among maize farmers was greatly influenced by formal education, extension education, and group membership. In rice production, formal education, off-farm income, and group membership were the major factors influencing both TE and AE. Economic efficiency among rice farmers was majorly influenced by credit access and off-farm income.

5.3 Conclusions

5.3.1 Conclusions for Objective One

Underuse of inputs contributed to farmers not attaining maximum output. For instance, in maize production, seed quantity used was the major determinant of output and it was underused. There is a great potential to increase maize output through the right use of seed quantities in East African wetlands. In rice production, land used was the major determinant of output and this shows that rice farmers have potential to sustainably expand rice plots in Kilombero wetlands considering that the general farm sizes in Kilombero wetlands are significantly bigger than those in Ewaso Narok and Namulonge wetlands. This also supports the sustainability of rice production expansion especially in initiatives such as the Tanzanian government’s Southern Agricultural Growth Corridor of Tanzania (SAGCOT) program of expanding rice production within the Kilombero wetland. Use of an optimal amount of fertilizers in rice production can help in increasing rice output and this lowers the rate of expansion of rice lands in the wetlands.

5.3.2 Conclusions for Objective Two

Maize farmers from the upland-irrigated system were the most technically efficient while those under the wetland-only system were the most allocative and economically efficient. The realization of maximum EE in rice production was more constrained by TE than EE.

5.3.3 Conclusions for Objective Three

In maize production, farmers who traveled for long distances to access the product market and extension education services were most likely to have the lowest TE while those that accessed credit for agricultural use had the greatest chance of maximizing their productivity. Also, bigger maize farming households where farmers also belonged to organized groups had the greatest chances of maximizing AE. In addition, maize farming in a Ugandan wetland reduced farmers' AE when compared to a Kenyan wetland. Maize farmers with formal education and belonged to organized groups were likely to maximize their EE, hence increasing their profits. Those who had low access to the market and the extension education services were likely to lower their EE. In rice farming, formally educated farmers who received off-farm income and were members of organized groups had a likelihood of maximizing their TE. Also, educated female farmers who earned off-farm income, and were members of organized groups were likely to maximize their AE. Those that were educated, belonged to organized farmer groups, and received off-farm could increase their EE than their counterparts did, and thus, they had increased their profit efficiency.

5.4 Recommendations for Policy Action

The County governments of Kyaddondo (Uganda) and Laikipia (Kenya), as well as the national governments, should guarantee adequate extension education to ensure appropriate input use in the wetlands' maize production. This will address issues of incorrect seed rate, pesticides application, and manure use rates in maize production regardless of the agricultural land-use system. This is a strategy to minimize wetland degradation due to the expansion of agricultural land in the wetlands along the unsustainable intensifications. In Tanzania, there is an opportunity for sustainable expansion of land under wetland rice production, therefore, governments and various stakeholders should also ensure proper inputs use, especially fertilizers, to encourage increased production with minimal degradation.

Maize production under the upland-irrigated system should be encouraged especially with alternative and subsidized water sources such as piped water or water harvested in dams through government initiatives and then supplied by either the national or the county governments. This system had the farmers with the highest TE and utilizing it can have positive effects on wetland sustainable production. Policymakers should develop interventions that encourage sustainable use of the upland-irrigated system in maize production to reduce pressure on the wetlands, hence lowering threats to their existence due to further drainage.

Both national and county governments can use policy instruments to strengthen arrangements that ensure farmers acquire formal education such as adult education since education has proven to be a significant determinant of both maize and rice farmers' technical efficiency. There should be more interventions leading to increased access to extension services and credit, which will enhance the affordability of yield-enhancing inputs and rightly using them.

5.5 Suggestions for further research

The current study addresses the productive efficiency of major staples (maize and rice) in East African wetlands as one of the ways to ensure sustainable wetlands agricultural production. However, wetlands sustainable agricultural production is also dependent on livestock production. There is, therefore, a suggestion for studies on livestock productive efficiency with regard to different livestock production systems namely intensive, semi-intensive, and extensive. This will ensure combined efforts to reduce East African wetlands degradation from both crop and livestock production.

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APPENDICES

Appendix 1: Critical ecosystem services obtained from wetlands

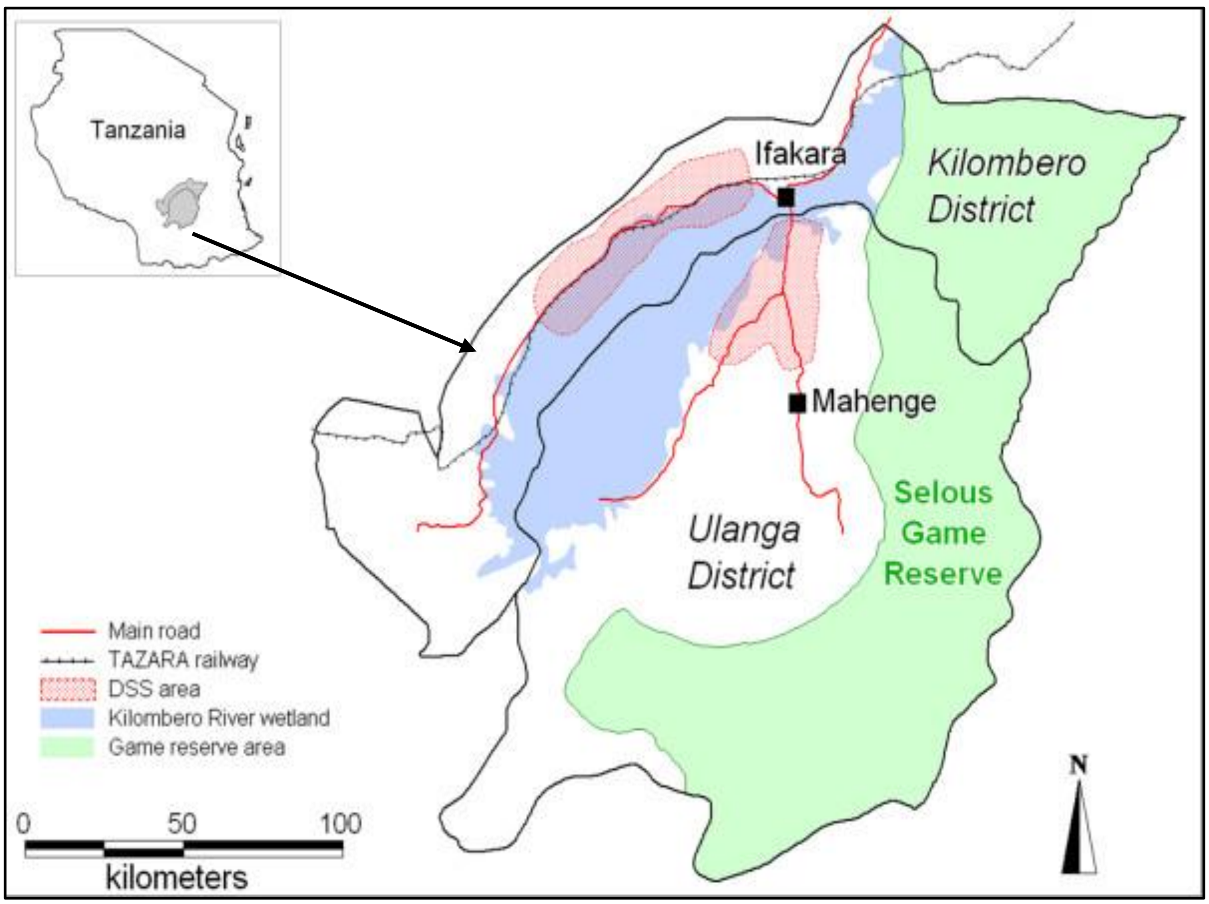
Services	Comments and examples
Provisioning	
• Food	• Food products e.g. fish, fruits, and grains
• Freshwater	• They store or retain fresh water for agricultural, industrial, and domestic use.
• Fibers and fuel	• Includes; fuel woods, fodder, logs, etc.
• Biochemicals	• These include substances with medicinal value
• Genetic material	• These include genes that give plants resistance to pathogens
Regulating	
• Regulation of climate	• Control greenhouse gases, including carbon through flora and fauna, which regulates local and global precipitation and temperature
• Hydrological flows regulation	• Includes discharge and recharge of groundwater
• Purification of water and treatment of waste	• Useful nutrients are retained while pollutants are removed
• Regulation of soil erosion	• Soils and sediments are retained
• Regulation of natural hazard	• The respective region is protected from floods and storms
• Pollination	• Provision of habitation for pollinators
Cultural	
• Ecosystems for inspirational and spiritual services	• Wetlands provide some cultural and religious values for some communities
• Recreational	• These include services like wildlife tourism
• Aesthetic	• Several aspects of wetland ecosystems provide beauty for many people
• Educational	• Several pieces of training, formal and informal education are carried out on wetlands

Appendix 1 continued: Critical ecosystem services obtained from wetlands

Supporting	
• Soil formation	• Enhances accumulation of organic matter while retaining sediments
• Nutrient cycling	• Nutrients are acquired, stored, recycled and processed
• Biodiversity	• They support biodiversity by providing various ecological niches

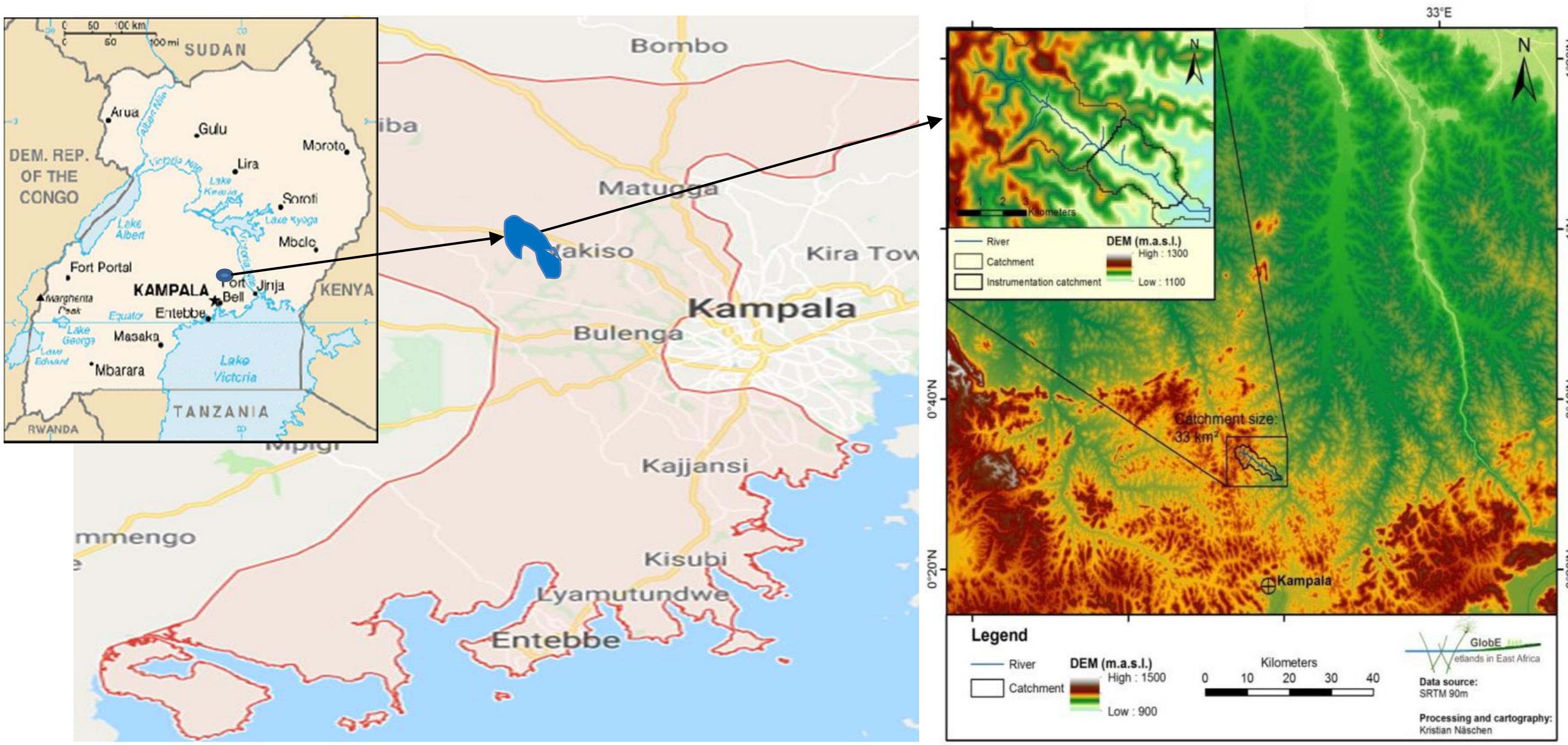
Source: Adapted from (IWMI, 2014; Wood *et al*., 2013)

Appendix 2: Maps showing the study areas

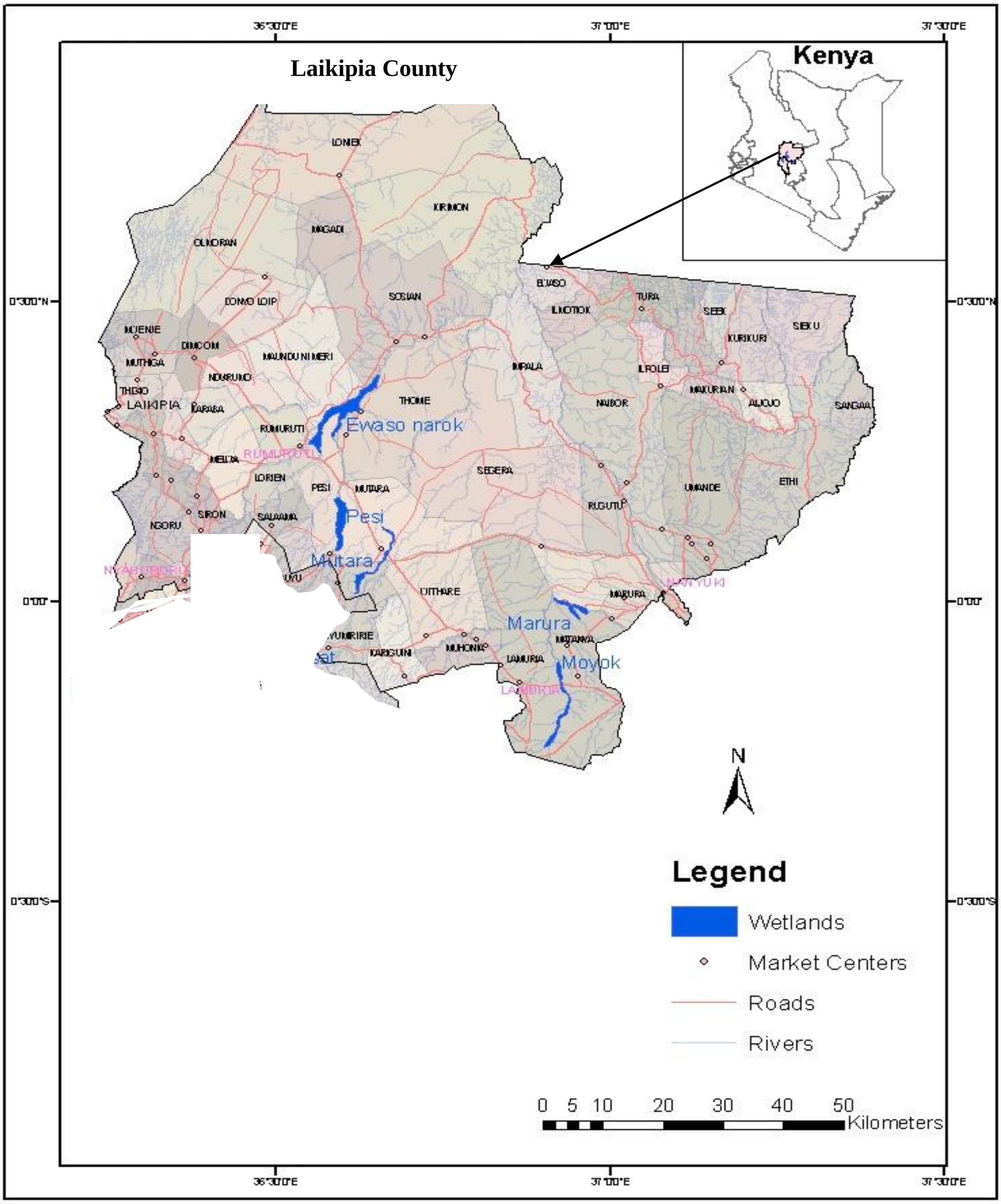


Map of Kilombero wetland
Source: Field survey, 2017

Uganda Wakiso District Namulonge wetland



Map of Namulonge wetland
Source: Field survey, 2017



Map of Ewaso Narok wetland
Source: Field survey, 2017

Appendix 3: Multicollinearity test results for maize and rice production inputs data in East African wetland

Variance inflation factors (vif) for maize production factors

Variable	VIF	1/VIF
lnlandha	1.87	0.535259
lnlabor	1.65	0.607744
lnmanure	1.22	0.820477
lnpfert	1.12	0.891117
lnseed	1.11	0.904002
lntpfert	1.1	0.908531
lnpestcd	1.1	0.913105
lnherbcd	1.03	0.967879
Mean VIF	**1.27**	

Variance inflation factors (vif) for rice production factors

Variable	VIF	1/VIF
lnlandha	1.3	0.769079
lnlabor	1.17	0.855517
lnpfert	1.25	0.802867
lnseed	1.05	0.951186
lntpfert	1.04	0.959152
lnpestcd	1.13	0.885821
lnherbcd	1.33	0.752008
Mean VIF	**1.18**	

Appendix 4: Heteroskedasticity test results for maize and rice production inputs data in East African wetland

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity for maize production

Ho: Constant variance

Variables: lnlandha lnseed lnpfert lntpfert lnlabor lnmanure lnpestcd lnherbcd

chi2 (8) = 1.05

Prob > chi2 = 0.3065

Breusch-Pagan / Cook-Weisberg test for heteroscedasticity for rice production

Ho: Constant variance

Variables: lnland lnseed lnpfert lnpestcd lnherbcd lnlabor lntpfert

chi2 (1) = 0.22

Prob > chi2 = 0.6404

Appendix 5: Missing variable test results for maize and rice production inputs data in East African wetland

Ramsey RESET test using powers of the fitted values of lnoutput (for maize production)

Ho: model has no omitted variables

F (3, 288) = 0.24

Prob > F = 0.8654

Ramsey RESET test using powers of the fitted values of lnoutput (for rice production)

Ho: model has no omitted variables

F(3, 134) = 0 .92

Prob > F = 0. 2367

Appendix 6: One-way ANOVA for maize production input use rates in East African wetlands

		Sum of Squares	df	Mean Square	F	Sig.
Seed quantity per ha	Between Groups	18.362	2	9.181	0.158	0.854
	Within Groups	17242.34	297	58.055		
	Total	17260.7	299			
Basal fert' qty per ha	Between Groups	3204.633	2	1602.316	0.751	0.473
	Within Groups	633335.8	297	2132.444		
	Total	636540.4	299			
Dressing fert' qty per ha	Between Groups	7287.15	2	3643.575	1.755	0.175
	Within Groups	616549.1	297	2075.923		
	Total	623836.3	299			
Man-days per ha	Between Groups	8295.955	2	4147.977	3.522	0.031
	Within Groups	349757.2	297	1177.634		
	Total	358053.1	299			
Manure fert' qty per ha	Between Groups	1420032	2	710016.2	0.104	0.901
	Within Groups	2.03E+09	297	6828711		
	Total	2.03E+09	299			
Pesticide qty per ha	Between Groups	245.259	2	122.629	8.051	0.000
	Within Groups	4523.528	297	15.231		
	Total	4768.787	299			
Herbicide qty per ha	Between Groups	159.03	2	79.515	9.565	0.000
	Within Groups	2469.119	297	8.314		
	Total	2628.149	299			
land under maize in hectares	Between Groups	5.193	2	2.596	5.165	0.006
	Within Groups	149.303	297	0.503		
	Total	154.496	299			
Output per hectare	Between Groups	17263716	2	8631858	9.019	0.000

Appendix 7: Distribution of TE, AE, and EE among Maize Producers in East African Wetlands

		Pooled		Upland-Rainfed		Upland-Irrigated		Wetland-only	
Efficiency	**Range**	**Number of farmers**	**Percent**	**Number of farmers**	**Percent**	**Number of farmers**	**Percent**	**Number of farmers**	**Percent**
	0-24	87	29	66	31.4	5	20.8	16	24.2
TE	25-49	90	30	70	33.3	4	16.7	16	24.2
	50-74	100	33.3	67	31.9	12	50	21	31.8
	75-100	23	7.7	7	3.3	3	12.5	13	19.7
	0-24	26	8.7	21	10	1	4.2	4	6.1
AE	25-49	129	43	107	51	7	29.2	15	22.7
	50-74	96	32	51	24.3	13	54.2	32	48.5
	75-100	49	16.3	31	14.8	3	12.5	15	22.7
	0-24	116	38.7	82	39	9	37.5	25	37.9
EE	25-49	116	38.7	79	37.6	12	50	25	37.9
	50-74	62	20.7	44	21	3	12.5	15	22.7
	75-100	6	2	5	2.4	0	0	1	1.5

Appendix 8: Distribution of TE, AE, and EE among Rice Producers in East African Wetlands

Efficiency	**Range**	**Frequency**	**Percent**
	0-24	12	8.3
TE	25-49	35	24.1
	50-74	59	40.7
	75-100	39	26.9
	0-24	7	4.8
AE	25-49	17	11.7
	50-74	38	26.2
	75-100	83	57.2
	0-24	29	20
EE	25-49	51	35.2
	50-74	44	30.3
	75-100	20	13.8

Appendix 9: *Post-hoc* tests for differences in mean efficiencies

Multiple Comparisons

LSD

Dependent Variable	**(I) Land Use**	**(J) Land Use**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
						Lower Bound	Upper Bound
TE	Upland-Rainfed	Upland-Irrigated	-.13656*	0.05037	0.007	-0.2357	-0.0374
		Wetland-only	-.11145*	0.03299	0.001	-0.1764	-0.0465
	Upland-Irrigated	Upland-Rainfed	.13656*	0.05037	0.007	0.0374	0.2357
		Wetland-only	0.02511	0.05572	0.653	-0.0845	0.1348
	Wetland-only	Upland-Rainfed	.11145*	0.03299	0.001	0.0465	0.1764
		Upland-Irrigated	-0.02511	0.05572	0.653	-0.1348	0.0845
AE	Upland-Rainfed	Upland-Irrigated	-0.05074	0.04104	0.217	-0.1315	0.03
		Wetland-only	-.07788*	0.02688	0.004	-0.1308	-0.025
	Upland-Irrigated	Upland-Rainfed	0.05074	0.04104	0.217	-0.03	0.1315
		Wetland-only	-0.02715	0.04541	0.55	-0.1165	0.0622
	Wetland-only	Upland-Rainfed	.07788*	0.02688	0.004	0.025	0.1308
		Upland-Irrigated	0.02715	0.04541	0.55	-0.0622	0.1165
EE	Upland-Rainfed	Upland-Irrigated	0.03456	0.04204	0.412	-0.0482	0.1173
		Wetland-only	-0.00536	0.02753	0.846	-0.0595	0.0488
	Upland-Irrigated	Upland-Rainfed	-0.03456	0.04204	0.412	-0.1173	0.0482
		Wetland-only	-0.03991	0.0465	0.391	-0.1314	0.0516
	Wetland-only	Upland-Rainfed	0.00536	0.02753	0.846	-0.0488	0.0595
		Upland-Irrigated	0.03991	0.0465	0.391	-0.0516	0.1314

*** The mean difference is significant at the 0.05 level.**

Appendix 10: Interview Schedule

Kenyatta University/GlobE Wetlands in East Africa Project
Household Survey 2017

We are part of a team at Kenyatta University, who are studying aspects wetlands crop production to determine the productive efficiency among maize and rice farmers. You have been randomly selected to take part in this survey and therefore your participation in answering these questions is very much appreciated, but purely voluntary and free to withdraw anytime during the interview. Your responses will be **COMPLETELY CONFIDENTIAL**. Your responses will be added to those of 445 other households and analyzed together. If you indicate your voluntary consent by participating in this interview, may we begin?

SECTION A: PRELIMINARIES

Survey Date: (dd/mm/yy) **SURDATE**[___________________]		**HHID** [_________]
HH Name [___________________________________]**HHNAME**	Cell phone number	**CELLPH**[______________________________]
Respondents name [_______________________________]**RESPO**		**MEM**[________]

(**Enumerator Instruction**: Record the member number of the Respondent from the demography table on **section F** after the survey is completed.)

Identifying Variables:		
Supervisor: [___________________________]		**SNUM**[____________]
Enumerator: [___________________________]		**ENUM** [___________]
District[______________________________]		**DIST**[_____________]
County[______________________________]		**CONT**[____________]
Sub-county: [___________________________]		**SCONT**[___________]
Ward[______________________________]		**WARD**[____________]
Parish: [______________________________]		**PAR** [_____________]
Village: [______________________________]		**VIL**[______________]

GPS coordinates:		
	(1=North 2=South) **NS______**	**Northing : ________' ______________dd**)
	East **_**	**Eastings** : ________' ______________**dd**)
		Alt : Altitude **m. a.s.l** (_________)

SECTION B: CROP PRODUCTION

RAIN-FED CROP PRODUCTION: MAIN SEASON 2016 (Feb-July 2016)

B1. Did this household have any cropping activity in **wetland fields** during **the MAIN CROP Season 2016?** (1= yes; no=2) **MAINCROPWET[________]**

B2. Did this household have any cropping activity in **upland fields** during **the MAIN CROP Season 2016?** (1= yes; no=2) **MAINCROPUP [_________]**

B3. If B1=1 and/or B2 =1, go to Table below; Otherwise move to the short season crop.

Crop code	Parcel No.	Field No.	Field Location 1=Wetland 2=Upland	Size of the field (Acres)	Tenure	Fertility status: 1=poor 2=fertile 3=very fertile	Main land prep type 0=none 1=manual 2=oxen 3=tractor	Hired land prep cost (Sh)	**Planting/ Seed Type** 1=Purch /New Hybrid 2=Retained Hybrid 3=OPV 4=local var 5=local seedling/cuttings/splits 6=improved seedling /cuttings /splits 7=hybrid& local var 8=hybrid purc+retained	Quantity of seed used & cost, if purchased this season			1st Fertilizer used			2nd Fertilizer used			3rd Fertilizer used			Harvest -777=not yet harvested		Sales		**For the largest Sale**				Quantity that spoiled after harvest **(Use harvest units)**	Reasons for spoilage 1=pests 2=floods 3=animal destruction 4=Rains 5=Moulds 6=No market 7=Other) specify)
										Qty	Unit	Cost per unit	Type	Qty	Unit	Type	Qty	Unit	Type	Qty	Unit	Qty	Unit	Sold? 1=yes 2=No	Quantity sold **(Use harvest units)**	Month 1= Jan. …….. 12=Dec	Price received per unit	Buyer type	Km to point of sale		
crop	**parc**	**field**	**Fldloc**	**acres**	**tenure**	**ferts**	**landprep**	**lpcost**	**Sdtype**	**sqt**	**sunit**	**scost**	**ft1**	**fq1**	**fu1**	**ft2**	**fq2**	**fu2**	**ft3**	**fq3**	**fu3**	**hvt**	**Hunit**	**sold**	**sqty**	**month**	**price**	**buyer**	**Km**	**postharv**	**spoilrea**

Unit codes: 1=90 kg bag 11=50 kg bag 2=Kgs 3=Litre 4=crates 5=numbers 6=bunches(bananas 9=gorogoro	10=tonnes 12=debe 13=grams 14=wheelbarrow 15=cart 16=canter 17=pickup 18=2kg packet(seed) 19=bale		**Fertilizer codes:** 0=None 1=DAP 2=MAP 3=TSP 4=SSP 5=NPK (20:20:0) 6=NPK (17:17:0) 7=NPK (25:5:+5S) 8=CAN (26:0:0)	9=ASN (26:0:0) 10=UREA (46:0:0) 11=SA (21:0:0) 12=Other (specify)___ 13=manure 14=foliar feeds 15=NPK (23:23:23)	16=NPK (20:10:10) 17=DAP + CAN 18=compost 19=magmax lime 20=DSP 21=NPK(23:23:0) 22=NPK(17:17:17) 23=NPK(18:14:12) 24=NPK(15:15:15)	25=mavuno-basal 26=kero green 27=rock-phosphate 28=NPK 14:14:20 29=mijingu 1100 30=UREA+CAN 31=Mavuno-top dress 32=Blended fertilizers	**Buyer type codes:** 1=small trader 2=large trader 3=KTDA 4=coffee coop 5=NCPB 6=miller 7=other coop 8=NGO	9=consumer 10=Exporter 11=processor 12=supermarket 13=cereal bank 14=pyrethrum board 15=Institutions 16=Other -specify	**Tenure codes** 1=owned w/ deed 2=owned w/o deed 3=rented in 4=owned by parent/ relative 5=government/communal/co-operative/road reserves 6=Leasehold 7=Other(specify)___________

RAIN-FED CROP PRODUCTION SHORT SEASON 2016 (August-Dec 2016)

B4. Did this household have any cropping activity in **wetland fields** during **the SHORT CROP Season 2016?** (1= yes; no=2) **SRTCROPWET[________]**

B5. Did this household have any cropping activity in **upland fields** during **the short CROP Season 2016?** (1= yes; no=2) **SRTCROPUP[__________]**

B6. If B4=1 and/or B5 =1, go to Table below; Otherwise move to the Irrigated crops Table .

Crop code	Parcel No.	Field No.	Field Location 1=Wetland 2=Upland	Size of the field (Acres)	Tenure	Fertility status: 1=poor 2=fertile 3=very fertile	Main land prep type 0=none 1=manual 2=oxen 3=tractor	Hired land prep cost (Sh)	**Planting/ Seed Type** 1=Purch /New Hybrid 2=Retained Hybrid 3=OPV 4=local var 5=local seedling/cuttings/splits 6=improved seedling /cuttings /splits 7=hybrid& local var 8=hybrid purc+retained	Quantity of seed used & cost, if purchased this season			1st Fertilizer used			2nd Fertilizer used			3rd Fertilizer used			Harvest -777=not yet harvested		Sales		**For the largest Sale**				Quantity that spoiled after harvest **(Use harvest units)**	Reasons for spoilage 1=pests 2=floods 3=animal destruction 4=Rains 5=Moulds 6=No market 7=Other) specify)
										Qty	Unit	Cost per unit	Type	Qty	Unit	Type	Qty	Unit	Type	Qty	Unit	Qty	Unit	Sold? 1=yes 2=No	Quantity sold **(Use harvest units)**	Month 1= Jan. ……... 12=Dec	Price received per unit	Buyer type	Km to point of sale		
crop	**parc**	**field**	**Fldloc**	**acres**	**tenure**	**ferts**	**landprep**	**lpcost**	**Sdtype**	**sqt**	**sunit**	**scost**	**ft1**	**fq1**	**fu1**	**ft2**	**fq2**	**fu2**	**ft3**	**fq3**	**fu3**	**hvt**	**Hunit**	**sold**	**sqty**	**month**	**price**	**buyer**	**Km**	**postharv**	**spoilrea**

Unit codes:
1=90 kg bag
11=50 kg bag
2=Kgs
3=Litre
4=crates
5=numbers
6=bunches(bananas
9=gorogoro
10=tonnes
12=debe
13=grams
14=wheelbarrow
15=cart
16=canter
17=pickup
18=2kg packet(seed)
19=bale

Fertilizer codes:
0=None
1=DAP
2=MAP
3=TSP
4=SSP
5=NPK (20:20:0)
6=NPK (17:17:0)
7=NPK (25:5:+5S)
8=CAN (26:0:0)
9=ASN (26:0:0)
10=UREA (46:0:0)
11=SA (21:0:0)
12=Other (specify)___
13=manure
14=foliar feeds
15=NPK (23:23:23)
16=NPK (20:10:10)
17=DAP + CAN
18=compost
19=magmax lime
20=DSP
21=NPK(23:23:0)
22=NPK(17:17:17)
23=NPK(18:14:12)
24=NPK(15:15:15)
25=mavuno-basal
26=kero green
27=rock-phosphate
28=NPK 14:14:20
29=mijingu 1100
30=UREA+CAN
31=Mavuno-top dress
32=Blended fertilizers

Buyer type codes:
1=small trader
2=large trader
3=KTDA
4=coffee coop
5=NCPB
6=miller
7=other coop
8=NGO
9=consumer
10=Exporter
11=processor
12=supermarket
13=cereal bank
14=pyrethrum board
15=Institutions
16=Other -specify

Tenure codes
1=owned w/ deed
2=owned w/o deed
3= Mailo land
4=rented in
5=owned by parent/ relative
6=government/communal/co-operative/road reserves
7=Other(specify)__________

CROP PRODUCTION: IRRIGATED CROPS

B7. Did this household have any irrigated cropping activity in **wetland fields** in the last cropping year (**2016)?** (1= yes; no=2) **IRRCROPWET[________]**
B8: If yes, what is the main method of irrigation used? 1=Drip 2=Furrow 3=Sprinkler/overhead 4=Bucket 5=(specify)_______________ **IRRMTDUP**[________]
B9. Did this household have any irrigated cropping activity in **upland fields** in the last cropping year (**2016)?** (1= yes; no=2) **IRRCROPUP**[________]
B10: If yes, what is the main method of irrigation used? 1=Drip 2=Furrow 3=Sprinkler 4=Bucket 5=Other specify)_______________ ____ **IRRMTDUP**[________]
B11: What is are the main ways through which you **abstract (draw) irrigation water**? 1=Water pump 2=Gravity 3=Bucket 4=other specify__________**WATERAB**[________]
B12. If B7=2 and/or B8 =2, go to **Table** below;

Crop code	Parcel No.	Field No.	Field Location 1=Wetland 2=Upland	Size of the field (Acres)	Tenure	Fertility status: 1=poor 2=fertile 3=very fertile	Main land prep type 0=none 1=manual 2=oxen 3=tractor	Hired land prep cost (Sh)	**Planting/ Seed Type** 1=Purch /New Hybrid 2=Retained Hybrid 3=OPV 4=local var 5=local seedling/cuttings/splits 6=improved seedling /cuttings /splits 7=hybrid& local var 8=hybrid purc+retained	Quantity of seed used & cost, if purchased this season			1st Fertilizer used			2nd Fertilizer used			3rd Fertilizer used			Harvest -777=not yet harvested		Sales		**For the largest Sale**				Quantity that spoiled after harvest **(Use harvest units)**	Reasons for spoilage 1=pests 2=floods 3=animal destruction 4=Rains 5=Moulds 6=No market 7=Other) specify)
										Qty	Unit	Cost per unit	Type	Qty	Unit	Type	Qty	Unit	Type	Qty	Unit	Qty	Unit	Sold? 1=yes 2=No	Quantity sold **(Use harvest units)**	Month 1= Jan. …….. 12=Dec	Price received per unit	Buyer type	Km to point of sale		
crop	**parc**	**field**	**Fldloc**	**acres**	**tenure**	**ferts**	**landprep**	**lpcost**	**Sdtype**	**sqt**	**sunit**	**scost**	**ft1**	**fq1**	**fu1**	**ft2**	**fq2**	**fu2**	**ft3**	**fq3**	**fu3**	**hvt**	**Hunit**	**sold**	**sqty**	**month**	**price**	**buyer**	**Km**	**postharv**	**spoilrea**

Unit codes: 1=90 kg bag 11=50 kg bag 2=Kgs 3=Litre 4=crates 5=numbers 6=bunches(bananas 9=gorogoro	10=tonnes 12=debe 13=grams 14=wheelbarrow 15=cart 16=canter 17=pickup 18=2kg packet(seed) 19=bale		**Fertilizer codes:** 0=None 1=DAP 2=MAP 3=TSP 4=SSP 5=NPK (20:20:0) 6=NPK (17:17:0) 7=NPK (25:5:+5S) 8=CAN (26:0:0)	9=ASN (26:0:0) 10=UREA (46:0:0) 11=SA (21:0:0) 12=Other (specify)___ 13=manure 14=foliar feeds 15=NPK (23:23:23)	16=NPK (20:10:10) 17=DAP + CAN 18=compost 19=magmax lime 20=DSP 21=NPK(23:23:0) 22=NPK(17:17:17) 23=NPK(18:14:12) 24=NPK(15:15:15)	25=mavuno-basal 26=kero green 27=rock-phosphate 28=NPK 14:14:20 29=mijingu 1100 30=UREA+CAN 31=Mavuno-top dress 32=Blended fertilizers	**Buyer type codes:** 1=small trader 2=large trader 3=KTDA 4=coffee coop 5=NCPB 6=miller 7=other coop 8=NGO	9=consumer 10=Exporter 11=processor 12=supermarket 13=cereal bank 14=pyrethrum board 15=Institutions 16=Other -specify	**Tenure codes** 1=owned w/ deed 2=owned w/o deed 3=rented in 4=owned by parent/ relative 5=government/communal/co-operative/road reserves 6=Leasehold 7=Other(specify)___________

SECTION C: CROP INPUTS

C1. Indicate the following details for CROP INPUTS purchased/hired in **CASH/CREDIT in 2016/17 cropping year for the LARGEST fields (ENUME: Probe for both the largest field in the wetland and the largest field upland.**

Input codes: 1=DAP 2=MAP 3=TSP 4=SSP 5=NPK (20:20:0) 6=NPK (17:17:0) 7=NPK (25:5:+5S) 8=CAN (26:0:0) 9=ASN (26:0:0) 10=UREA (46:0:0) 11=SA (21:0:0) 13=Manure 14=Foliar feeds 15=NPK (23:23:23) 16=NPK (20:10:10) 17=DAP + CAN 19=Magmax Lime 20=DSP 21=NPK (23:23:0) 22=NPK (17:17:17) 23=NPK (18:14:12) 24=NPK (15:15:15) 58=NPK(25:5:0) 25=Mavuno-basal 26=Kero green 27=Rock-phosphate 28=NPK 14:14:20 29=Mijingu 1100 30=UREA+CAN 31=Mavuno-top dress 43=NPK (22:6:12)	32=pesticide (Name__________ 33=insecticide (Name__________ 34=herbicide 35=plough 36=sprayer 37= AT equip 39=technical support 40=fungicide 41=water 46=planter cost 47=harvester cost 48=transport 49=sheller cost 50=fuel 51=gunny bags 52=ridger cost 53=land rent 54=land preparation cost(on credit only) 55=farm implements 56=farm machinery 57=irrigation equipment 12=other, specify_____ 58=Kelphos	**Unit** 1=90 kg bag 11=50 kg bag 2=kgs 3=litre 4=crates 5=numbers 6=bunches (bananas) 7=25kg bag 8=10kg bag 9=gorogoro 10=tonnes 12=debe 13=grams 14=wheelbar row 15=cart 16=canter 17=pickup 18=2kg packet (seed) 19=bale	**Field** 1=Largest wetland field 2=Largest upland field **(ENUME**: **Probe specifically for both)**	**Input type** (Select input codes from column on the left)	**Quantity** bought/ hired/ visits	**Unit (bought)**	**Quantity used/** hired/ visits	**Unit (used)**	**Mode of Purchase** 1=own cash 2=borrowed cash 3=in kind credit 4=own and borrowed cash 5=voucher	**Source of Fertilizer and other inputs** **Source type codes:** 1=small trader/ 2=Stockist/agrovet 3=large company 4=CBO 5=KFA 6=coffee coop 7=farmer /neighbor 8=KTDA 9=Other coop 11=Farmer group 12=Relative or friend 13=Government/NCPB 14=other, specify______	**Price per unit** specified	**Kms** from point of purchase to farm
			FLDINPU	**INPTYP**	**INQBGT**	**UNITBT**	**INQUSED**	**UNIT**	**INPRH**	**INSOURCE**	**INPUNIT**	**INDIST**

C2: What is the total land owned by your household in the wetland area in **ACRES**? **wetlandown[____]**
C3 What is the total land owned by your household in the upland area in **ACRES**? **uplandown [____]**
C4. What is the rental price (Shs) for an **acre of land** in the wetland annually? **rentalwet[____]**
C5: What is the purchase price (Shs) for an acre of land in the wetland in this village? **wlandprice[____]**
C6: What is the rental price (Shs) for the same acre in the upland annually **rentalup**[____]
C7: What is the purchase price (Shs) for one acre of land in a non-wetland area in this village? **uplandprice[____]**
C8: For the largest fields in the wetland and upland, indicate the following historical details for the last 10 years

	Year	Number of months when the field was left fallow		Did you apply organic fertilizers on this field? 1=yes 2=no		Did you apply inorganic fertilizers on this field? 1=yes 2=no		Did you rent-in any land within the wetland in the year? 1=yes 2=no		If yes, what was the size of land rented-in (acres)?	
		Wetland field	**Upland Field**	**Wetland field**	**Upland Field**	**Wetland field**	**Upland Field**	**Wetland field**	**Upland Field**	**Wetland field**	**Upland Field**
		wetfallow	**upfallow**	**orgwet**	**upwet**	**inorgwet**	**inorgup**	**rentwet**	**rentup**	**sizewet**	**sizeup**
1	**2016**										
2	**2015**										
3	**2014**										
4	**2013**										
5	**2012**										
6	**2011**										
7	**2010**										
8	**2009**										
9	**2008**										
10	**2007**										

(ENUMERATOR: Ask the amount in local currency and then convert into EURO: 1 EUR= 112 KES, 2340 TZS, and 3670 UGX)

SECTION D: LABOUR INPUTS

D1: Did you have a **salaried** employee (s) during the last one year? 2016 (1=yes; 2=No; **If NO, skip to D4**) **salary** [_______]

D2: If Yes, how many **salaried** employees did you have in your farm? **Semploy** [_____]

D2: If yes, what was your total **monthly expenditure** on salaried employees in Shs **salexp** [_____]

D3: How many months cumulatively between Feb 2016 and Jan 2017 did the salaried employees work on the **wetland largest field**? **salmon** [____]

D4: What is the daily wage rate for farm work in this area in Shs? **Wage**[_____]

D5: For all the family, hired and unpaid labour that was used in your wetland largest field in the **main season**, indicate the following details

Activity name		**Hired Labour**				**Family Labour (adults)**						**Family Labour (children)**			**Other Labour (ONLY if unpaid)**		
	Code	No hired	No of days per person	Shs per person per day	Total Shs by contract	No of males	Total No of days worked by **ALL**	Average number of hours worked **per person per day**	No of females	Total No of days worked by **ALL**	Average number of hours worked **per person per day**	No of children <15 yrs	Total No of hours each	Total Hours for all days worked	No of workers	No of days worked each	No of hours per day each (on average)
	ACTIV	**LB01**	**LB02**	**LB03**	**LB04**	**LB05**	**LB06**	**LB07**	**LB08**	**LB09**	**LB10**	**LB11**	**LB12**	**LB13**	**LB14**	**LB15**	**LB16**
1st Ploughing	1																
2nd Ploughing	2																
Digging planting holes																	
Harrowing	3																
Planting	4																
Basal fertilizer application																	
Manure application																	
1st Weeding	5																
Top-dressing	6																
2nd Weeding	7																
Field Dusting	8																
Harvesting	9																
Transport	10																
Drying	11																
Digging drainage canals	12																
Other (specify)_________																	
Other (specify)_________																	

D6: Relative to the labour input in the wetland, how much labour was applied on the upland largest field? **uplabour**[_____]

1= about the same 2=approx. 50% less 3= approx.50 % more 4=approx. 25% more 5=approx. 25% less 6= Other, specify___________________

SECTION E: HOUSEHOLD ASSETS (PROMPT for each item as listed below)

At present, how much/many of the following does this household **own** that are **usable/repairable**?

(**Enumerator Instructions**: For value per unit, ask for the current purchase price of the asset as is or the current market value of the asset as it is.)

		Quantity	Current value per Unit (Shs)	If Value/Unit not known ask for Total Value			Quantity	Current value per Unit (Shs)	If Value/Unit not known ask for Total Value
CODE	**ASSET**	**QTY**	**VALUE**	**TOTVAL**	**CODE**	**ASSET**	**QTY**	**VALUE**	**TOTVAL**
1	Houses (residential)				31	Trailer			
2	Stores/barns				32	Ploughs for tractor			
3	Poultry houses				33	Harrow/tiller			
4	Piggery houses				34	Ridger/weeder			
5	Zero-grazing units				35	Planter			
6	Wheel barrow				36	Boom sprayer			
7	Chaff cutter				37	Sheller			
8	Radio				38	Combine harvester			
9	TV				39	Generator			
10	Solar panels				40	Power saw			
11	Battery				41	Grinder			
13	Mobile Phone				42	Jaggery unit			
14	Weighing machine				43	Cane crusher			
15	Pestle and mortar				44	Donkey			
16	Water tanks				45	Oxen			
17	Beehive				46	Animal traction plough			
18	Water pump				47	Cart			
19	Borehole				48	Posho mill			
20	Dam				49	Sewing/knitting machine			
21	Well				50	Fridge			
22	Irrigation equipment				51	Stove			
23	Cattle dip				52	Panga			
24	Spray pump				53	Jembe			
25	Water trough				54	Other, specify			
26	Bicycle				55	Other, specify			
27	Motorcycle				56	Other, specify			
28	Car				57	Other, specify			
29	Truck				58	Other, specify			
30	Tractor				59	Other, specify			

SECTION F: HOUSEHOLD DEMOGRAPHIC INFORMATION

F1: Indicate the following details for **all the household members** who **were home** for **atleast one month** within the **last one year** (**2016).**

ID	Name	In which **year** was this person born?	Gender 1=male 2=female	**Relation ship** to **current** head ***See codes below***	Marital Status ***See codes below***	Is..... **Curren-tly** attending school? 1 = Yes 2 = No	What is the **highest** level of education completed? ***See codes below***	How many years have you cultivated the crop since you made the decision to be a maize/rice farmer?	Is this person **still** considered **a member** of this household? 1 = Yes 2 = No	If this per-son is **not a member** of this house-hold any-more, **why**? ***See codes below***	Did this person receive cash from **informal employ-ment / business / kibarua / dividends** between Feb 2016 & Jan 2017? 1=Yes 2=N*o*	If YES, mon-thly income estimate (Sh) for the months in which informal income was earned	Number of months in the past year in which this informal income was earned	Did this person receive cash or payment in kind from **salaried employment/ remittances or pensions** ? 1=Yes 2=No	If YES, monthly income estimate (Sh)	Number of months in the past year in which this salaried income was earned	Has your household **borrowed money** or goods (including seeds or fertilizer) from any source in the past five years? 1=Yes 2=No
MEM	**NAME**	**DA01**	**DA02**	**DA03**	**DA04**	**DA05**	**DA06**	**DA07**	**DA08**	**DA09**	**DA10**	**DA11**	**DA12**	**DA13**	**DA13**	**DA14**	**DA15**
1.																	
2.																	
3.																	
4.																	
5.																	
6.																	
7.																	
8.																	
9.																	
10.																	
11.																	

Relation to head(DA03)		**Marital Status(DA04)**	**Education levels(DAO6)**			**Reason for absence (DA09)**	
1= head	9= grandchild	1 = single	-99=don't know	9= form1		1=left to find a job	9=Left to attend school
2= spouse	10=other relative	2 = married-monogamous	-9=None	…	20=univ 2	3=married away	10= Other, specify___
3= own child	11=unrelated	3 = married- polygamous	0=pre school	14=form 6	21=univ 3	4=deceased	
4= step child	12=brother /sister-	4 = divorced	1=std 1	15= college 1	22=univ 4	5=divorced /separated	
5= parent	13=parent-in-law	5 = widowed	…	…	23=univ 5	6=living with other relatives	
6= brother /sister	14=worker	6 = separated	8=std 8	18= college 4	24=postgrad	7=another household	
7= nephew /niece	15=Other specify	7 = other, specify______		19= univ 1		8=went missing	
8= son/daughter-in-law							

INCOME FROM OTHER SOURCES

F2: Did any member of the household earn some **income from other sources** between Feb 2016 and January 2017? **Otherinc**[______]

F3: If yes, indicate the total amount earned within the period in the table below.

Income source	**Monthly income (Shs)**	**Annual Income (Shs)** *(Incase the income was earned once within the year)*
Remittances		
Rental income (Land)		
Rental income (Buildings)		
Income from farm outside the area		
Income from business		
Other(specify)		
Other(specify)		

F4. Is there a member of the household who is a member of any organized group in the community? 1=yes; 2=no -- *If YES, go to the **Table** below* **GROUPMEM**[_______]

Household member ID from demog Table	Major **group activities** (up to 3) (*See codes below*)			Number of **active members** in the group	Frequency of meetings (*See codes below*)
MEMID	**GRUPACT1**	**GRUPACT2**	**GRUPACT3**	**GROUPSZ**	**MEETNG**
Activities: 1=Collective labor (soil and water conservation); 2= Collective labor (other farm activities); 3=Collective crop marketing; 4=Savings and credit services; 5=Bee keeping; 6= Collective training on farming activities; 7=Collective learning on soil and water conservation; 8=Merry-go-round; 9=Other(specify)___________________				**Frequency**: 1=Weekly; 2=Fortnightly; 3=Monthly; 4=Quarterly; 5=Semi-annually; 6=Annually; 7=When need arises; 8=Other (specify)____________	

SECTION G: INFRASTRUCTURE

G1: What is the distance from your home to the nearest shopping centre? **Distshop [____]**
G2: What is the distance from your home to the nearest tarmac road? **Disttmk [_____]**
G3: What is the distance from your home to the nearest health centre? **Disthc [_____]**
G4: What is the distance from your home to where you can tap electricity? **dstele [_____]**
G5: What is the distance from your home to where you can get piped water? **dstpipe[____]**
G6: What is the distance from your home to public/private extension services? **stext[____]**
G7: What is the distance from your home to the nearest river/stream? **dsrver[____]**
G8: What is the distance from your home to the wetland? **dswet[____]**

Thank you for participating in this survey