BRIDGING THE GAP BETWEEN FOOD SECURITY AND ENVIRONMENTAL SUSTAINABILITY THROUGH AGRICULTURAL PRODUCTIVE EFFICIENCY: CASE OF EAST AFRICA'S WETLANDS

***Lucy Gathoni Njogu[1] Daniel Kyalo Willy[1&2] and Eric Kiprotich Bett[1]**

1. Kenyatta University, School of Agriculture and Enterprise Development 2. African Agricultural Technology Foundation

Contacts: *1st author: lucy.njogu@hotmail.com
2nd author: kyalodaniel@gmail.com
3rd author: kiprotiche@gmail.com

Abstract

Attaining zero hunger has been a difficult goal for nations and organizations, especially due to climate change (Action against Hunger, 2019; Food and Agriculture Organization, 2018), which has resulted to frequent droughts and erratic rainfall. As a result, farmers try to counter shocks failure by acquiring plots in high potential areas such as wetlands. However, unsustainable agricultural activities in the wetlands threaten the ability of the wetlands to provide their ecosystem services such as regulating climate and supporting livelihoods (Ramsar Convention, 2016). It is important that a balance is obtained between food production and environmental sustainability, particularly in the wetlands. Land policies, especially when based on problem specific research, play a critical role in achieving food security and environmental sustainability. In order to increase productivity, farmers either encroach further into the wetlands or intensify their use of inputs. However, productive efficient farmers obtain the highest possible output using the least possible inputs, such as land and fertilizer. The current study sought to determine how land size among other production factors as well as socio-economic and institutional factors influence productivity. The study was guided by three research questions; 1) What is the level of profit efficiency of spinach farmers in East Africa's wetlands. 2) How does the size of the vegetable plot influence profit efficiency? 3) What are the institutional and socio-economic factors that influence the profit efficiency? Data were collected from spinach farmers in Ewaso-Narok wetland in Kenya and Namulonge in Uganda. A Cobb-Douglas profit function was used to determine the profit efficiency scores while a Tobit model was used to analyze the determinants of profit efficiency. The mean profit efficiency score was 0.51, implying that by increasing efficiency, farmers would increase profitability by 49%. The relationship between land size and profit efficiency was inverse and significant which indicates that increase in the vegetable plot size only leads to reduced profitability. The significant determinants of profit efficiency were the level of education, distance to the market and access to agricultural extension, access to credit, and household size. It is therefore recommended that governments formulate land planning interventions which ensure that part of the wetland is left fallow to enhance sustainability. Agricultural extension services should also be made accessible to the wetland farmers.

Key words: Wetlands, sustainability, land policies, efficiency

Introduction

Every night, 11% of the world's population sleeps on an empty stomach while in every 10 seconds, a child dies from the effects of hunger (Welthungerhilfe, 2019; World Food Programme, 2019). There are 821 million people in the world who do not get enough food to lead a normal life, inferring that 1 in 9 people are undernourished and in every three persons, one suffers from some form of malnutrition (WFP, 2018). In Africa, the situation of food insecurity is more pressing, particularly in Sub-Saharan Africa where about 23.2% of the population experienced hunger in 2017. In East Africa, the rate of food insecure population rose from 30.2% in 2015 to 31.6% in 2016 (FAO, 2018).

Food insecurity worsened due to the rapidly growing population and urbanization, resulting to increased demand for food. It is projected that that by 2030 the population in Africa will be equal to that of Asia. In Kenya for example, the population has doubled within 45 years, making the current population more than 40 million people (World Bank, 2010) while in Uganda, the rate of population growth is 3.2% per annum (UBOS, 2014). Environmental degradation and climate change are major causes of food insecurity due to the increased frequencies of droughts and more erratic rainfall. Rainfall deficiency results to food insecurity due to the cascading effect on agricultural productivity and food prices, consequently affecting both the households' incomes and food availability (FAO, 2018). Low income households are particularly vulnerable to climate change driven food insecurity, as their livelihoods are natural resources dependent (Mariara and Kabara, 2015; FAO, 2008). To counter the increased demand for food and shocks resulting from reduced productivity from the upland fields and climate change, farmers tend to shift to more potential areas such as wetlands.

Wetlands are high potential areas that support livelihood in various ways. Crop production is a common activity in wetlands due to availability of water and fertile soil, which enables these ecosystems to support crop production even during the dry seasons. In the Sub-Saharan Africa, 93% of all the 143 sites designated as wetlands of international importance by the Ramsar Convention, support agriculture (IWMI, 2010). Globally, the economic value of wetlands is estimated to be 14 trillion USD (Millennium Ecosystems Assessment, 2005). The estimated economic loss resulting from wetlands degradation in Uganda is about 0.7 billion USD per annum (UNDP, 2016a). In Kenya, the value of fisheries contributed about 0.54% of the country's GDP in 2013 (FAO, 2014), which implies that if other products and services from Kenya's wetlands were valued, the contribution to GDP would be higher (Mwangi, 2017). However, wetlands in East Africa are facing pressure mainly from agricultural activities, causing rapid rate of degradation. Wetlands degradation results to a vicious cycle between loss of biodiversity, low productivity and loss of income, causing a myriad of economic challenges.

According to UNDP (2017), wetlands are being lost at approximately 2% per year, globally and this is particularly a major problem in developing nations (Gong et al., 2010; Huang et al., 2011; Song et al., 2012). In Uganda, it is estimated that wetlands coverage decreased from 15% of the land area in 1994 to 10% in 2014 while in Kenya, the area under swamps reduced by 40% between 1970 and 2003 (Kecha *et al*., 2007). According to Tumuhimbise (2017), about 20.5 hectares in the Namulonge wetland in Uganda had undergone significant land cover change between 1986 and 2014, indicating significant loss of the wetland mainly due to agricultural activities.

Degradation of wetlands from agricultural activities occur through various ways, some of which include conversion of wetlands into farm lands, extraction of ground water for irrigation and use of agrochemicals which degrade the wetlands. In bid to obtain food and income, farmers attempt to increase productivity by draining more wetlands to grow crops, and by increasing their input use. Extensive and unsustainable intensification in wetlands result to degradation that further reduces productivity. Given that the role of wetlands is projected to increase and that the drivers of wetlands utilization are also predicted to intensify, it is important that these resources are efficiently utilized, to ensure their future ability to support livelihoods. Particularly, crop production should be carried out in a manner that ensures optimal productivity in order to curb food insecurity and also through agricultural practices that minimize negative externalities to the environment, to ensure sustainability. As such, productive efficiency is critical in bridging the gap between food security and environmental sustainability. Achieving optimal productivity means that farmers obtain the highest possible output, given the quantity of inputs. Alternatively, farmers may achieve productive efficiency by producing certain quantity of output, while using the minimum possible inputs.

Owing to the fact that vegetables are mainly grown to provide income through profit maximization, the study analyzed productive efficiency by employing a profit efficiency approach. The study focused on spinach farmers due to the critical role that the crop plays in providing micronutrients that curb malnutrition, hence improving food security. Also, spinach is a horticultural crop that provides income to the farmers which in return ease the problem of food security and over reliance of natural resources for subsistence production. In addition, spinach farming is a common activity among farmers in East African wetlands. It is against this backdrop that study analyzed the determinants and levels of profit efficiency of spinach farmers in East African Wetlands. The study was guided by three research questions; 1) What is the level of profit efficiency of spinach farmers in East Africa's wetlands. 2) How does the size of the vegetable plot influence profit efficiency? 3) What are the institutional and socio-economic factors that influence the profit efficiency?

Materials and Methods

The study was conducted within two wetlands; Ewaso Narok and Namulonge. Ewaso Narok wetland is an upland flood plain in Kenya, located in the Western area of Laikipia County near Rumuruti. Namulonge is an inland valley wetland in Uganda close to Kampala and Lake Victoria, in Wakiso District. The primary data used in this study were obtained through a cross-sectional survey among 130 randomly selected farm households located near the target wetlands in Kenya (60) and Uganda (70). The sample size was determined using the (Kothari, 2004) formula while ensuring a reasonable precision and confidence level. Interview schedules were used to collect data on production, socio-economic and institutional factors from vegetable farmers. Two approaches were used to collect data from the two wetlands, where a two-step method was used in Kenya and a three-step process used in Uganda, because the study area is dotted with small wetlands, unlike in Kenya where the wetland is well defined. In Ewaso Narok, a list of all the villages within and around the wetland was developed with the help of administrative officers and knowledgeable village elders. A sample of villages was then randomly selected, while ensuring that the entire wetland area was well represented. A sampling frame of spinach growing households was then generated separately, and a sample of households to be interviewed randomly chosen.

Empirical Framework

To estimate the level of profit efficiency and determine how land size influence profitability, a Cobb –Douglas functional form was used and specified as follows:

$$Ln\pi = \beta_0 + \beta_1 \; inZi + \beta_2 \; lnP_{1i} + \beta_3 \; lnP_{2i} + \beta_4 \; lnP_{3i} + \beta_5 \; lnP_{4i} + \beta_6 \; lnP_{5i}$$

$$+vi - ui \text{ ....(1)}$$

Where $Ln\pi$ represents the profits obtained by each farmer from the spinach enterprises, calculated as the gross margin derived from revenue and production cost. The vectors indicated as lnP_{1i} to lnP_{5i} are the average price per unit of fertilizer, seeds, pesticides and labor, of the ith farm. The variable $inZi$ is the fixed factor variable; represented by the area of plot under spinach, β_1 to β_6 vector of parameters. The variables were standardized using the out price per unit, then linearized by converting them in to logarithms. V is the random variable which represents the stochastic effect outside the farmer's control and U is the efficiency component representing profit inefficiency

To assess the determinants of profit efficiency, a two-limit Tobit was used. The efficiency scores obtained lie between 0-1, and therefore the suitability of the Tobit regression.

The empirical specification was specified as follows:

$$PE_i = \beta_0 + \Sigma_{n=1}^{13} \beta_n Q_i + \varepsilon_i \text{ ....(2)}$$

Where:

PE_i Represents the profit efficiency scores and β_n represents the parameters to be estimated. Q_i represents the socio economic and institutional factors that influence profit efficiency. The socio economic and institutional variables which were estimated include gender, age and level of education of the household head, access to credit, distance to the agricultural extension offices, distance to the market, access to credit, household size, farming experience, type of buyer, group membership and location of the wetland. The type of buyer was in three categories, institutions/companies, local market/road side traders, broker and consumer and therefore dummy variables were used and consumer used as a base variable. A dummy variable on the country of wetland location was used to determine whether there was any difference in efficiency between Kenya and Uganda. To estimate the profit efficiency scores and the influence of plot size on profitability, the profit function was run on Frontier IV software while STATA 13 was used analyze the Tobit model.

Results and Discussion

The range of size of total wetland parcel owned was between 0.04 ha and 4.45 ha while the mean size of plots allocated to the spinach was 0.136 ha, meaning that East African wetlands spinach farmers are mainly small scale. In addition to subsistence purposes, farmers may allocate more land to maize and beans due to the cyclical prices associated with vegetable crops, that sometimes lead to large losses, (Bett and Ayieko, 2017). Allocation of small pieces of land to vegetables may indicate crop diversification tendency, where farmers may subdivide land into different crop plots in order to minimize risk (Ullah *et al*., 2015). The sampled households used wetland for various purposes, in addition to crop production. Some of these source of livelihood activities included obtaining building poles, fuel, cut and carry fodder, fishing, roofing materials, brick making, weaving and basketry.

Majority of the sampled households solely depended on farm income as the results indicate that only 32% of the farmers had income from other sources. Further, out of the 32% who obtained off-farm income, 77% obtained an average 136 KES. per day which is below the international poverty line of approximately 190 Kes. Per day (Jolliffe & Prydz, 2016). All of the sampled households had used the wetland for over ten years, being that the wetland was the only available resource, as cited by 65% of the interviewed wetland users. Other common reasons cited for preference of wetland for the diversified purposes were close proximity to the users' homes, fertile soil, scarcity of land and fodder elsewhere as well as food shortage. Given the large proportion of households that cited wetland as the only available resource, it may be deduced that most of these farmers were resource-poor, indicating the risk of wetlands' overexploitation since the resource-poor over-rely on natural resources (USAID, 2006). Only 10% of the sampled households had plans to leave their land fallow over the next one year.

The mean profit efficiency of spinach farmers was 0.44, minimum being 0.09, maximum of 0.82 and a standard deviation of 0.19. The most inefficient farmer would need to increase profit efficiency by 89%, to be at par with the most efficient enterprise ([(1-(09/82)) x 100]]). Based on the efficiency scores, if farmers utilized the resources efficiently, they could have obtained additional KES 286, 350 per ha as indicated on Table 1. If farmers operated their spinach enterprises efficiently, they would obtain Spinach enterprises a monthly income of KES 42611. The income generated could have a positive influence on farmers' livelihoods, for instance through an enhanced ability to purchase food instead of subsistence production of all the required food crops, therefore easing overexploitation and rate of degradation of wetlands.

The coefficient of plot size was significant and negative at 5% and the elasticity was -0.31, as indicated on Table 2. This implies 1% increase in the size of land under spinach would decrease the profitability of the enterprise by 0.31. Various studies have reported different relationships between land size and efficiency. Some researchers have found an inverse relationship between land size and efficiency (Larson *et al*., 2014; Ali & Deininger, 2015; Barrett *et al*., 2010; Carletto *et al*., 2013), while others like Muyanga & Jayne (2017) found that farmers with medium size land were the most efficient, and Mburu *et al*. (2014) found that efficiency among wheat farmers increased with increase in land size.

Vegetable farming requires attention and strict agronomic practices such as frequent inspection and timely application of pesticides among other inputs. Therefore, the inverse relationship between land size and profitability could emanate from the complexity of vegetable farm management associated with increase in land size, such as efficiency in use of inputs which may result into increase in costs without necessarily increasing revenue, if not appropriately carried out. The Tobit model estimates indicated that access to extension services, group membership, level of education, access to credit, household size, and off farm income had a significant influence on profit efficiency, as indicated on Table 3. The results indicate that access to agricultural extension services was the most important determinant to profit efficiency, implying that farmers who had access to these services were more efficient than those who did not.

Conclusion and Policy Implications

The inefficiency scores show that farmers did not operate on the profit frontier, indicating underutilization of resources. It shows that more income could be obtained, which is critical for food security. In addition, despite that the natural resources were put into use, the opportunity cost resulting from degradation did not optimally translate to food security. Farmers could reduce minimize costs to obtain the same amounts of profits. Reducing the inputs and costs imply that the wetlands are more sustainably used since agricultural inputs are detrimental to the wetlands if unsustainably used.

The size of wetland converted to agricultural production is a critical determinant of the resource's resilience and ability to provide ecosystem services. In order to obtain maximum possible income, farmers do not need to encroach further into the wetlands, in fact, increasing plot size was found to negatively influence profitability. The inverse relationship between land size and profitability indicate that in East African wetlands, profitability from spinach enterprises may be increased while still reducing land size under crop, therefore drawing closer to the elusive balance between food production and wetlands sustainability. Farmers do not have to encroach further into the wetlands to increase the income from the vegetable enterprises.

In order for farmers to achieve profit efficiency in their enterprises, agricultural extension services should be adequately provided to the farmers in East African wetlands. High quality seeds should be made available to the farmers as the increase profit efficiency. This could be done by making credit more accessible to farmers, as currently, less than half of the vegetable farmers have access to credit. On the same note, agricultural extension offices should be provided nearer to the wetlands as the increase in the distance to these services reduce profit efficiency. It is recommended that the government in each of the two countries formulate land planning interventions which ensure that part of the wetlands is reserved from crop production, to enhance sustainability. Some plots should be left fallow to allow the ecosystem to go through the wet and dry cycles to enhance sustainability. Agricultural extension officers may work in collaboration with environmental conservation officers, who may provide additional expertise in ensuring wetlands sustainability.

References

Action against Hunger (2019) World Hunger: Key Facts and Statistics. Available at https://www.actionagainsthunger.org/world-hunger-facts-statistics

Bett, E. K., & Ayieko, D. M. (2017). Economic Potential for Conversion to Organic Farming: A Net Value Analysis in the East Mau Catchment, Nakuru, Kenya. *Environ Dev Sustain*, 1307-1325.

FAO. (2015). *Fact Sheet on Food and Agriculture Policy Trends: Country Situation and Role of Agriculture.* FAO. Retrieved from http://www.fao.org/3/a-i4915e.pdf

FAO. (2015). *FAO Statistical Pocketbook World Food and Agriculture.*

FAO. (2015). The Role of Market Information. *Food and Agricultural Organization*.

FAO. (2015). *TheState of Food Insecurity in the World: Meeting the 2015 hunger Targets, Taking Stock of Uneven Progress.* Retrieved from www.fao.org/publications

FAO. (2017). *Africa; Regional Overview of Food Security and Nutrition: The Challenges of Building Resilience to Shocks and Stresses.* Accra: Food and Agricultural Organization of the United States.

FAO. (2009). *Growing Vegetables for Home and Market.* Rome: FAO: Food and Agricultural Organization

FAO (2018). Africa: Regional Overview of Food Security and Nutrition. Addressing the Threat from Climate Variability and Extremes for Food Security and Nutrition

Food and Agriculture Organization (2018). 2018 The State of Food Security and Nutrition in the World: Building Climate Resilience for Food Security and Nutrition. Available at http://www.fao.org/3/i9553en/i9553en.pdf

Food Aid Foundation (2019). Hunger Statistics. Available at https://www.foodaidfoundation.org/world-hunger-statistics.html

Jolliffe, D., & Prydz, E. B. (2016). *Estimating International Poverty Lines from Comparable National Thresholds.* Worldbank

Mburu, S., Ogutu, C. A., & Mulwa, R. (2014). Analysis of Economic Efficiency and Farm Size: A Case Study of Wheta Farmers in Nakuru District, Kenya. *Economic Research International*.

Mohapatra, S., Mohapatra, U., & Mishra, R. K. (2017). Diversification towards Vegetable Crops: AGood Option for Doubling the Farmer's Income. *Journal of Experimental Agriculture*, 18(4):1-7.

Ramsar Convention Secretarait. (2016). *: An Introduction to the Convention on Wetlands.* Gland, Switzerland: Ramsar Convention Secretarait.

Rebelo, L., McCartney, M., & Finlayson, C. (2009). Wetlands of Sub-Saharan Africa: Distribution and Contricution of agriculture to livelihoods. *Springer*.

The Centre for International Governance Innovation (2009). CIGI Special Report: Climate Change in Africa: Adaptation, Mitigation and Governance Challenges. UNICEF

Ullah, R., Jourdain, D., Shivakoti, P., & Dhakal, S. (2015). Managing catastrophic risks in agriculture: simultaneous adoption of diversification and precautionary savings. *International Journal of Disaster Risk Reduction*, 268-277.

USAID. (2006). *Issues in Poverty Reduction and Natural Resource Management.* United States Agency for International Development.

Welthungerhilfe (2019). Hunger: Facts and Figures. Available at https://www.welthungerhilfe.org/hunger/

World Food Programme (2018). 2018-Hunger Map. Available at https://www.wfp.org/content/2018-hunger-map

World Food Programme (2019) Zero Hunger. Available at https://www1.wfp.org/zero-hunger

Appendices

Table 1

	Profit Efficiency	Actual Profit	Max. possible profit	Profit Loss

Spinach	0.44	224989	511339	286350

Table 2

Variables	Elasticity	Std. Error.	P-Value
ln plot size	-0.31**	0.19	0.002
ln ave. cost of seeds (Kes./kg)	0.51***	0.06	0.000
ln ave. cost of fertilizer (Kes./kg)	-0.28	0.53	0.595
ln ave. cost of labor (Kes./man-day)	0.51	0.71	0.478
ln ave. cost of pesticides(Kes./kg)	-0.36**	0.12	0.002
ln ave. cost of manure (Kes/kg)	-0.09	0.31	0.755
sigma_v (σ_v)	0.4036	0.0773	
sigma_u (σ_μ)	1.9353	0.1415	
lambda (λ)	2.3731	0.1817	
gamma (γ)	0.9583	0.2006	
Likelihood-ratio test of σ_μ=0			
Chibar^2(01)	13.50		
Prob>=chi^2	0.000		
Wald chi^2(5)	154.07		
Prob > chibar^2	0.000		
Log likelihood	-147.75		

Table 3

Variable	Estimated Coefficient	Std. deviation	P Value
Age	-0.002	0.001	0.171
Gender	-0.003	0.047	0.948

Education	0.004*	0.002	0.094
HH Size	-0.013*	0.007	0.060
Distance to market	-0.005	0.051	0.177
Access to extension	-0.212***	0.001	0.000
Farming experience	0.001	0.002	0.525
Institutions/companies	-0.015	0.049	0.747
Local market	-0.064	0.137	0.088
Brokers			
Off-farm income	0.200***	0.032	0.000
Credit access	0.077*	0.029	0.010
Group Membership	0.165*	0.001	0.073
Wetland Location	-0.019	0.100	0.847
Constant	0.555	0.110	0.000