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MSc. Dissertation

Growing Rice under Stressed Water Availability: An Economic Evaluation of Irrigation Technologies in Kilombero Sub-Basin, Tanzania

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GROWING RICE UNDER STRESSED WATER AVAILABILITY: AN ECONOMIC EVALUATION OF IRRIGATION TECHNOLOGIES IN KILOMBERO SUB-BASIN, TANZANIA

Dissertation Submitted In Partial Fulfillment of the Requirements for the Degree of Master of Science in Agricultural and Applied Economics

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EXTENDED ABSTRACT

Growing rice in Tanzania's major basins is threatened by climate change impacts. It is projected that rice yield will fall by 7.6% in these major basins in aggregate. Climate change impacts in Tanzania's major basins including Kilombero sub-basin (KSB) which is the biggest feeder of Rufiji basin is attributed to increasing temperature which accelerates surface evaporation. There is also increased water demand due expanding agriculture, influx of livestock and water for hydropower generation. Climate change impacts and increasing water demand in the sub-basin have called for planned and sustainable use of water. One of the implemented techniques is the new adaptive rice growing technologies. Irrigation technologies like traditional flooding irrigation technology (TFIT) for rice farming that exposes water to surface evaporation is no longer a viable adaptation technology for growing rice under stressed water availability from scientific point of view. Alternatively, the system of rice intensification (SRI) irrigation has recently been encouraged in KSB by the Ministry of Agriculture (MoA) to reduce water loss through surface evaporation through controlled water usage. However, 90% of rice irrigable land in KSB is still under flooding irrigation which is inefficient in use of water.

From literature there is enough evidence in agronomic point of view that SRI irrigation is more water use efficient than TFIT but information on their economic efficiency at household level especially in KSB is not readily available. This study was conducted in Kilombero district to evaluate the profitability of TFIT and SRI irrigation technologies and the determinants of profitability of the two irrigation technologies and; factors that determine the choice of rice irrigation technology in KSB. Data were collected through Focus Group Discussions (FGDs), Key Informant Interview (KIIs) and household survey that involved 100 households. The study used farm budget method to evaluate profitability (Net Revenue) of rice produced under SRI and TFIT.

From Net Revenue (NR) obtained, profitability determinants were evaluated using multiple linear regressions. This represented first published paper on the economics of the irrigation technologies. Furthermore, this study used the reduced household model to evaluate factors that motivate farming households to decide on the type of rice irrigation technology and allocation of production resources between the two technologies *in situ* SRI and TFIT which is the second published paper.

The findings from first published paper (on economics of SRI irrigation and TFIT) have shown that on average rice production costs per acre are TZS 471 572.5 and 248 939.9 for SRI and TFIT respectively. Also, the study found that on average farming households practicing SRI and TFIT produce 1268 and 608 Kgs of threshed rice respectively per acre. Adding on that the average NR per acre under TFIT and SRI were TZS 902 236 and 1 276 841 respectively, indicating that SRI irrigation was more profitable than TFIT. Despite being more profitable, the findings have shown that SRI is more labour intensive than TFIT; a farming household practicing SRI needs to supply an average of 23 man-days per acre per season while a household practicing TFIT has to supply 14 man-days per acre per season. On one hand, the study found that farming experience, farm size, fertilizer application, agricultural supporting services like capital assistance and high frequency of extension visits positively and statistically influenced the profitability of both SRI and TFIT but differed in magnitudes for example each increment in extension visit caused a TZS 169 000 increase in SRI compared to TZS 101 000 in TFIT *ceteris paribus*. One of the notable recommendations from the findings is that the subsidization to industrial fertilizers is the viable option by the MoA to benefit rice farmers who irrigate using SRI principles and traditionally. Also increasing extension officers is important especially in areas found with inadequacy like Sululu.

Results from second published paper (on choice determinants for rice irrigation technology) have shown that demographic aspects like household headship and years spent education predicted land allocation and labour requirement for TFIT or SRI irrigation. For example, incremental unit in rent for land reduced land allocation for SRI (0.57 acre) compared to TFIT (0.52 acre) because of the expensiveness of SRI plots in irrigation schemes.

Moreover, each additional year spent by household head in education caused an average increase of 73 Kgs in rice production of SRI irrigation compared to 41 Kgs of TFIT. Also, each incremental year of farming experience of household head resulted to more increase in land allocated for TFIT (0.78 acre) compared to SRI irrigation (0.63 acre). Moreover, male headed households allocated an average of 0.68 acres more land for SRI irrigation compared to their counterparts. Furthermore, education was found to increase external income which eventually caused household decision in favor of SRI irrigation since external income enabled SRI irrigation users to cover additional costs not common in TFIT like labour cost for alternate wetting and drying.

From the findings, this study has concluded that even though SRI is labour intensive but it is economically profitable than TFIT. The study has also concluded that households consider so many factors when choosing the technology to use in rice production. It is further revealed through this study that households consider the opportunity cost time across various economic activities at their disposal. In choosing the type of technology to use labour time emerged as the major concern of households. Many households preferred TFIT more than SRI because of labour requirement. Education of a household head also is one of the factors influencing decision between the two technologies; households headed with an experienced farmer preferred TFIT more than SRI indicating that they are more concerned of labour requirement.

Finally, non-farm income also emerged as one of the key factors; in this case households engaging more in activities other than rice farming preferred SRI than TFIT implying that they have income to invest in SRI which is more profitable than TFIT. From these findings, SRI is the better rice production practice than TFIT in KBS. However, any promotion of this technology should take into account of the factors identified from findings. They indicate that households in the area are rational and they take into account so many factors before they finally decide on irrigation technology to use. Further, the promotion of SRI could go in line with provision of financial support that will help farmers to finance different farm activities.

This is because the technology needs high initial investment that entails costs to households. Helping them financially will bust adoption in the sub-basin and this will be one of the ways to adapt the prevailing climate change variability which is experienced in the sub-basin.

Keyword: Sub-Basin, Irrigation Technologies, Kilombero and Farming Households

IKISIRI KUU

Kilimo cha mpunga kwenye mabonde makubwa ya Tanzania kinahatarishwa na athari za mabadiliko ya tabia nchi. Inakadiriwa mavuno ya mpunga kwenye mabonde hayo yatashuka kufikia asilimia 7.6. Aidha, athari za mabadiliko ya tabia nchi kwenye bonde kama la Kilombero zinasababishwa na kuongezeka kwa joto ambalo hupelekea uvukizi la anga. Katika bonde la Kilombero kumekuwa pia na ongezeko la uhitaji wa maji kutokana na kupanuka kwa kilimo, kuongezeka kwa mifugo poja na uwepo wa mitambo ya kuzalisha umeme unaotokana na maji. Athari za mabadiliko ya tabia nchi na kuongezeka kwa uhitaji wa maji kwa pamoja vimepelekea kuja na mipango ya utumiaji maji endelevu. Moja kati ya mipango na mikakati inayotekelezwa ni teknolojia mpya endelevu za kulima mpunga. Teknolojia za umwagiliaji kama kumwagilia kwa kutuamisha maji ili kulima mpunga siyo endelevu kwakuwa hutumia maji mengi ambayo hupotelea hewani kupitia uvukizi. Teknolojia hii kisayansi haifai katika mazingira ambayo mpunga unalimwa kukiwa na upatikanaji wa maji usio wa uhakika. Kufuatia hilo, umwagiliaji shadidi wa mpunga umekuwa ukipendekezwa zaidi na wizara ya kilimo kwenye bonde la Kilombero kupunguza kupotea kwa maji bila ulazima. Licha ya hayo yote, asilimia 90 ya eneo linalolimwa mpunga kwenye bonde hilo bado linamwagiliwa kwa kutumia teknolojia ya kienyeji ya kutuamisha maji ambayo haina ufanisi kwenye matumizi ya maji.

Kuna uthibitisho wa kutosha wa kiagronomia kwamba kumwagilia mpunga kwa kutumia shadidi kuna ufanisi zaidi kwenye matumizi ya maji ikilinganishwa na umwagiliaji wa kutuamisha maji kienyeji, lakini uthibitisho kwa kuzingatia ufanisi uchumi wa teknolojia hizi zote mbili kutokea kwenye kaya bado haujatolewa. Utafiti huu ulifanywa bonde la Kilombero kwenye wilaya ya Kilombero kutathmini; faida ya kumwagilia mpunga kwa kutuamisha maji kienyeji na kumwagilia kwa shadidi, sababu zinazopelekea faida

hiyo na, sababu zinazochangia kuchagua teknolojia ya kumwagilia mpunga. Takwimu za utafiti zilipatikana kupitia majadiliano ya ana kwa ana na kaya 100 zinazolima. Utafiti ulitumia njia ya bajeti ya shamba kutathmini faida ya mpunga uliolimwa kupitia umwagiliaji shadidi na wa kutuamisha maji kienyeji. Tathmini ya faida na sababu zake ilikamilisha sehemu ya kwanza ya utafiti huu kama andiko lililochapishwa.

Matokeo kutoka andiko lililochapishwa linalohusu faida ya kumwagilia kwa kutumia shadidi na kwa kutuamisha maji kienyeji yameonesha kwamba kwa wastani gharama za uzalishaji wa mpunga kwa ekari ni Shilingi za Kitanzania 471 572.5 na 248 939.9 kwa shadidi na kutuamisha kienyeji mtawalia. Pia, utafiti uligundua kwamba kwa wastani kaya za kilimo zinazofanya umwagiliaji shadidi wa mpunga na kutuamisha maji kienyeji kwa ekari huzalisha kilo 1268 na 608 za mpunga mtawalia. Faida kwenye ekari ya teknolojia ya kutuamisha kienyeji na shadidi ilikuwa ni shillingi za Kitanzania 902 236 na 1 276 841 mtawalia, ikionesha kwamba umwagiliaji wa shadidi ulikuwa na faida zaidi kuliko ule wa kienyeji. Licha ya kuwa na faida zaidi, utafiti umebaini kuwa umwagiliaji shadidi unatumia nguvu kazi zaidi kuliko ule wa kienyeji; kaya ya kilimo inayotumia umwagiliaji shadidi inahitaji kutoa wastani wa siku 23 za kazi kwa ekari kwa msimu huku kaya inayotumia umwagiliaji wa kutuamisha wa kienyeji inatoa siku 14 za kazi kwa ekari kwa msimu. Kwa upande mwingine, utafiti umegundua kwamba uzoefu katika kulima, ukubwa wa shamba, matumizi ya mbolea, huduma wezeshi kama msaada wa mtaji na idadi ya ziara za ugani ziliongeza kwa njia chanya faida ya umwagiliaji katika teknolojia zote mbili, lakini kulikuwa na utofauti wa kiwango cha ongezeko. Kwa mfano kila ongezeko katika ziara ya ugani ilisababisha ongezeko la shilingi za kitanzania 169,000 katika shadidi ikilinganishwa na shilingi za kitanzania 101,000 kwenye umwagiliaji wa kienyeji. Kutokanana na matokeo hayo, hitimisho muhimu la kisera ni kwamba ruzuku kwa mbolea za viwandani ni chaguo linalofaa kwa wizara ya kilimo katika kuleta tija kwenye kilimo cha mpunga bila kujali aina ya teknolojia ya umwagiliaji inayotumika. Pia, kuongeza idadi ya maafisa ugani ni muhimu hasa katika maeneo yenye upungufu kama Sululu.

Matokeo kutoka kwenye sehemu ya pili ya utafiti huu (juu ya mambo yanayochagua teknolojia ya umwagiliaji wa mpunga) yameonesha kuwa masuala ya kijamii kama jinsia ya kiongozi wa kaya na miaka iliyotumika katika elimu zilikuwa na uwezo wa kutabiri ugawaji wa ardhi na mahitaji ya nguvu kazi kwa teknolojia hizi zilizofanyiwa tathmini. Kwa mfano, ongezeko la kodi ya shamba lilipunguza ugawaji wa ardhi kwa upande wa shadidi (ekari 0.57) ikilinganishwa na umwagiliaji kienyeji (hekta 0.52) kwa sababu ya gharama kubwa ya mashamba ambako umwagiliaji shadidi unafanywa katika skimu za umwagiliaji. Mbali zaidi, kila mwaka zaidi uliotumika na kiongozi wa kaya katika elimu ulisababisha ongezeko la wastani la kilo 73 katika uzalishaji wa mpunga wa umwagiliaji wa shadidi ikilinganishwa na kilo 41 za ule wa kienyeji. Pia, kila mwaka wa uzoefu wa kilimo wa kiongozi wa kaya ulisababisha ongezeko la ardhi iliyotengwa kwaajili ya umwagiliaji wa kienyeji (ekari 0.78) ikilinganishwa na umwagiliaji wa shadidi (ekari 0.63). Zaidi ya hayo, kaya zinazoongozwa na wanaume zilitenga wastani wa hekta 0.68 za shamba zaidi kwa umwagiliaji shadidi ikilinganishwa na wanawake. Zaidi ya hayo, elimu imegunduliwa kuongeza mapato ya nje ambayo mwishowe yalisababisha uamuzi wa kaya kupendelea zaidi umwagiliaji shadidi kwani mapato ya nje yaliwezesha watumiaji umwagiliaji shadidi kumudu gharama za ziada ambazo hazipo katika umwagiliaji wa kienyeji kama gharama za nguvu kazi za kuloanisha na kukausha shamba kila inapohitajika kufanyika.

Kutokana na matokeo hayo, utafiti huu umehitimisha kwamba ingawa umwagiliaji shadidi unatumia nguvu kazi zaidi, bado una faida zaidi kiuchumi kuliko ule wa kienyeji wa kutuamisha maji. Utafiti pia umehitimisha kuwa kaya huzingatia mambo mengi wanapochagua teknolojia ya kutumia katika uzalishaji wa mpunga.

Pia, imethibitika kupitia utafiti huu kwamba kaya huzingatia gharama ya muda katika shughuli mbalimbali za kiuchumi wanazoweza kufanya. Kaya nyingi zilipendelea zaidi kumwagilia kienyeji kwa kutuamisha baadala ya shadidi kwa sababu ya mahitaji yake madogo ya siku za kufanya kazi. Elimu ya kiongozi wa kaya pia ni moja ya mambo yanayoathiri uamuzi katika kuchagua teknolojia hizi mbili; kaya zinazoongozwa na mkulima mwenye uzoefu wa kilimo zaidi zilipendelea kumwagilia kienyeji kuliko shadidi, ikionesha kwamba wana wasiwasi zaidi na mahitaji ya nguvu kazi. Hatimaye, mapato ya nje ya shamba pia yalitokea kama moja ya mambo muhimu; katika kesi hii, kaya zinazojihusisha zaidi na shughuli nyingine zaidi ya kilimo cha mpunga walipendelea shadidi kuliko kumwagilia kienyeji ikimaanisha kuwa wana pesa ya ziada kuwekeza katika shadidi ambayo ni faida zaidi kuliko kumwagilia kienyeji. Kiujumla, kutokana na matokeo haya, kumwagilia mpunga kwa kutumia kanuni za shadidi ni njia bora zaidi ya uzalishaji wa mpunga kuliko ule wa kienyeji wa kutuamisha maji katika bonde la Kilombero. Walakini, uendelezaji wowote wa teknolojia hii unapaswa kuzingatia mambo yaliyotambuliwa kutokana na matokeo ya utafiti huu. Aidha, kukuza umwagiliaji shadidi wa mpunga kunapaswa kwenda sambamba na utoaji wa msaada wa kifedha ambao utasaidia wakulima kumudu gharama kwenye uzalishaji. Hii ni kwa sababu teknolojia shadidi inahitaji uwekezaji mkubwa wa awali ambao unahusisha gharama kwa kaya. Kuziwezesha kaya kifedha kutaimarisha ushiriki wa wakulima katika bonde la Kilombero katika kilimo endelevu hivyo, kukabiliana na athari za mabadiliko ya tabia nchi.

Maneno muhimu: Bonde, Teknolojia za umwagiliaji, Kilombero na Kaya zinazolima.

DECLARATION

I, Martin Emmanuel Komba, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor concurrently being submitted in any other institution.

___________________ _______________

Martin Emmanuel Komba Date

(Msc. Candidate)

The above declaration is confirmed by;

___________________ _______________

Dr. Gody Jonathan Sanga Date

(Supervisor)

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DEDICATION

To Emmanuel Komba and Rehema Gondwe (my parents)

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LIST OF ABBREVIATIONS AND ACRONYMS

FGD	Focus Group Discussion
GoT	Government of Tanzania (GoT)
JNHPP	Julius Nyerere Hydropower Project
KII	Key Informant Interview
KSB	Kilombero Sub-Basin
MoA	Ministry of Agriculture
NR	Net Revenue
R&D	Research and Development
SAGCOT	Southern Agriculture Growth Corridor of Tanzania
SCGS	small holder farmers credit guarantee scheme
SRI	System of Rice of Intensification
TARI	Tanzania Agricultural Research Institute
TFIT	Traditional Flooding Irrigation Technology (TFIT)
TR	Total Revenue
TVC	Total Variable Cost
TZS	Tanzanian Shilling

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Problem

Tanzania is blessed with water resources which include lakes and rivers. The county has nine major basins which are Pangani, Rufiji, Ruvuma and Southern Coast, Wami Ruvu, Lake Nyasa, the internal drainage basin, Lake Rukwa, Lake Tanganyika and Lake Victoria. These lakes and basins are recharged by rain water which in recent years has become unpredictable in terms of quantity and raining period (Upton & Sanga, 2018;Hella *et al*., 2020). Such rainfall unpredictability is attributed to climate change, which has made water availability in basins to be affected (Makarius *et al*., 2015). The impact of climate change on the water basins is evidenced by a decrease in runoff of about 17% over the past decade (Makarius *et al*., 2015). Following these effects, the capacity of these water basins to support agricultural activities is projected to fall significantly. Projections indicates that the yield of crops like maize, sorghum and rice on average will decline by 13%, 8.8% and 7.6 % respectively in all the nine water basins by 2050 (Kahimba *et al*., 2015).

Kilombero sub-basin (KSB) which is part of Rufiji basin is one of the victims of climate change effects. The sub-basin holds up to two third of water that flows through the Rufiji basin (Dinesen, 2017). The sub-basin plays the role of being the water sponge of the Rufiji main basin. The area has numerous wetlands that receive water from Udzungwa scarp, percolate it and slowly release it downstream through the Rufiji River. Recent studies show that the temperature in the sub-basin is increasing by 0.03°C annually, and rainfall on the other hand is fluctuating between 500mm to 1500mm annually (FCFA, 2021). Increasing temperatures increases surface evaporation and fluctuating rainfall decreases the amount of rain and hence runoff in the streams and rivers recharging the sub-basin (Soderberg, 2014). Hydrological estimates indicate that water flow in streams and rivers recharging the sub-basin has fallen by 5% over the past decade (Wilson *et al*., 2016).

The estimates further confirm the severity of the impact of climate change on the sub-basin as it will eventually affect water availability for agriculture (Näschen *et al*., 2019). Such climatic trend caused by climate change on rainfall and temperature in sub-basin not only threaten the current water availability required to support human activities such as Julius Nyerere Hydropower Project (JNHPP) and irrigation farming but also the future.

Irrigation farming is among human activities that are largely taking place upstream in the Kilombero sub-basin (Höllermann *et al*., 2021). In the efforts of expanding production of food crops, the Government of Tanzania (GoT) through the *Kilimo kwanza* initiative, encouraged irrigated rice farming in the sub-basin for the purpose of increasing production level (URT, 2011; Wilson *et al*., 2016). Also, the Southern Agriculture Growth Corridor of Tanzania (SAGCOT) initiatives emphasizes on intensive agricultural production using irrigation scheming system. The KSB has been prioritized in production of rice under irrigation among the designated SAGCOT (Näschen *et al*., 2019). Given the fact that crop under consideration is the water demand intensive crop, increased irrigation schemes are undeniably increasing water demand in sub-basin regardless of the aforementioned water availability stress (Höllermann *et al*., 2021).

Furthermore, the increasing water demand for water can be triggered by rice irrigation technologies that are used in the sub-basin (Olson *et al*., 2015). Irrigation technologies like flooding irrigation (i.e. traditional) technology is scientifically mentioned to consume bulky of water in irrigation of rice as the technology allows a lot of water to be lost through surface evaporation. To reduce water loss through surface evaporation, the government through

Ministry of Agriculture (MoA) introduced System of Rice Intensification (SRI) technologies that intensify water use by reduce water loss. One of the principles in this irrigation technology is the controlled water usage. Under SRI it is assured that preciseness in providing plant with water in accordance with its requirement. This irrigation technology has been proven agronomically to be relatively efficient in water usage (Kadigi *et al.*, 2020).

Following the introduction of SRI irrigation, it was expected that farmers will switch from the traditional flooding irrigation technology (TFIT) to SRI irrigation. However, more than 90% of the sub-basin irrigable land is still under TFIT (Olson *et al*., 2015). This shows that more investigations need to be done on rice irrigation technologies that can be used under stressed water availability in the sub-basin. From agronomic perspective it is clear that irrigation under SRI is water use efficient but it is not clear about its economic efficiency. Farming household as decision making unit always aims at optimizing utility and profit at the same time by making various decisions on how to produce. It is from this fact that evaluating the economic viability of rice irrigation technologies deemed imperatives in justification of agronomic water use efficiency of the technologies. Economic evaluation of the rice irrigation technologies provides a validation of costs involved and potential benefits of each technology at household level.

1.2 Problem Statement and Justification

Agronomically, SRI irrigation technology is viable under stressed water availability situations, consequently the technology is expected to be adopted by many farmers. However, most part of irrigated land in KSB is under TFIT which exposes water to surface evaporation. In addition, efforts have been made to induce shift from TFIT to SRI irrigation with little success, 90% of irrigated land in the sub-basin is still under TFIT. This entails that further investigation to understanding factors hindering shifting from TFIT to SRI irrigation technologies is important. The searching for knowledge on hindering factors is the important step in inducing SRI adoption in KSB because continuing with practicing TFIT will jeopardize future availability of water in KSB as highlighted earlier. Economic evaluation of the two irrigation technologies will help bridging the existing gap of knowledge to policy makers.

So far, understanding that is available is on the comparison of the impact of the two on the efficiency of water usage in terms of quantity and impact on soil nutrients. For example Gowele (2020) and Eliya (2016) compared the two irrigation technologies on silicon and nitrogen usage efficiency. The two studies revealed that

irrigation under SRI is efficient in utilizing the two nutrients compared to traditional flooding irrigation because the later tend to cause leaching making the two nutrients not available to the plants. Little information is available on economics of the two irrigation technologies for example Katambara *et al.* (2013) and Styger (2019) who found more profitability of SRI over TFIT in Mbarali and Timbuktu respectively. Nevertheless, analyses in these studies of profitability were not made from household level. As previously noted, household aim at maximizing utility and profits when they make decisions, therefore, leaving them out of equation in evaluation of efficiency of the two irrigation technologies creates information biasness. To bridge the gap created by this analytical biasness this study used the household as a decision unit to study the economic viability of the two irrigation technologies in KSB.

1.3 Significance of the Study

The findings from first part of this study (which is about profitability of TFIT and SRI irrigation) are vital to policy makers to know which rice irrigation technology is more profitable than the other especially in KSB (one of the major designated areas for irrigation schemes).

In addition, findings from what factors significantly explaining profitability in both SRI and TFIT would communicate what policy intervention to be undertaken by responsible ministry to improve the profitability of respective rice irrigation technologies. For instance, interest rate of agricultural loans can be lowered by ministry of finance if borrowing by rice farmers has been found significantly increases profit level.

The findings from second part of this study (which is about the reasons for rice producing household to choose irrigation technology) are very useful to policy makers and other interested actors in rice subsector. Such usefulness comes through providing understanding on what farming household considers before adopting irrigation technology to use in rice farming. In response, interventions such as incentivizing factors found significantly influencing SRI choice could come in to discourage the application of convectional irrigation (TFIT).

In addition, this study is the baseline for other imminent studies in KSB especially those relating to determinants of profit efficiency among SRI adopters. Also, studies linked to irrigated agriculture, assessment of SRI adoption impact and/or livelihood outcomes among SRI adopters even in areas other than KSB are expected to use findings from this study.

1.4 Objectives of the Study

1.4.1 Overall objective

To evaluate the economics of rice irrigation technologies in KSB under anticipated water availability stresses emanated from climate change impacts.

1.4.2 Specific objectives

i. To evaluate profitability determinants of TFIT in KSB
ii. To evaluate profitability determinants of SRI irrigation in KSB
iii. To analyze factors influencing the choice of irrigation technologies for rice farming at household level in KSB.

1.4.3 Research Questions

i. What are the profitability determinants of TFIT in KSB?
ii. What are the profitability determinants of SRI irrigation in KSB?
iii. What are the factors determining the choice of rice irrigation technologies in KSB?

1.5 Theoretical Framework

As a unit of analysis in this study, household often invests resources to maximize both profit and utility at the same time. After all, household decision to use a particular irrigation technology is made after considering risks after its choice. It is from these household attributes; classical profit maximization, random utility and adoption are taken as the underpinning theories for this study.

Classical profit maximization theory mainly assumes that profit maximization is the only relevant goal that any rational producer or firm always strive to achieve (Ndabila, 2018). The theory is useful to this study especially when considering that rational rice farmer in KSB as the household can be pulled to go for the irrigation technology that maximizes his desires including profit. Random utility on the other hand assumes that individual makes choices from a particular set of alternatives. This study is therefore applying utility theory in analyzing the farmers' choice of irrigation technology to supplement the classical profit maximization theory that excludes utility part. Adoption theory proposes that an economic unit needs information in making rational calculation to accept innovation or technology with minimal chance of risk and uncertainties (Negatu and Parikh, 1999; Ngwira *et al*., 2014). This study borrows propositions from adoption theory since it is centered on farming household to accepting SRI irrigation or continuing with TFIT.

1.6 Conceptual Framework

As depicted from utility and profit theories in totality, rice producing households strive to maximize both utility and profit at the same time. In this regard, the framework is thus made up of four interlinked components, namely farming household, natural resources *in situ* water and land, production and economy. The structure of this relationship is hereafter explained. Farm household invest inputs such as family labour, seeds and fertilizers for maximization of their goal to be realized through production. As shown in the Figure 1.1, farm household has to interact with the nature by investing on natural resources i.e. water and land to produce rice. But this interaction is often distorted when natural factors like extreme weather conditions happen. Appropriate irrigation technology comes in place to enable production of crops given the conditions. If production successfully happens, the household harvests crops which are either consumed or sold. Both consumption and commercialization send feedback to farming household in terms of total utility derived and profit gained as seen in feedback loop. This is vital to rice producing household because the received feedback often determines the decisions in the next cropping season.

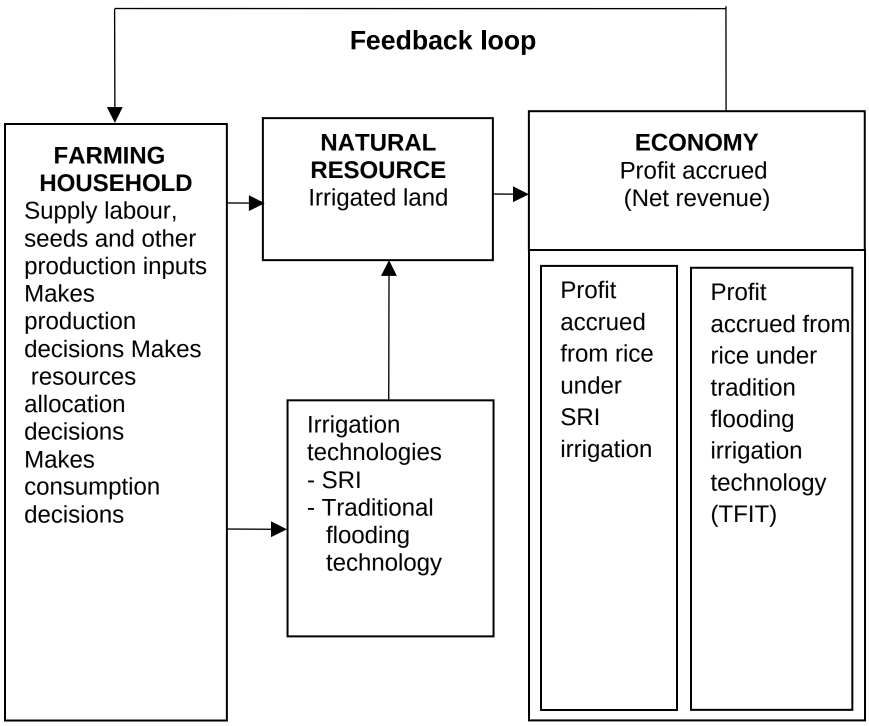

Figure 1.1: Conceptual framework for the study (Source: own conceptualization)

Feedback loop from economy component to farming household component is the profit accrued and total utility derived from rice harvested. This feedback loop can enable farmer to know which rice irrigation technology is more profitable than the other as broadly explained in the next chapter on the profitability of SRI and TFIT. Moreover, farming household passes through process with many things to consider before deciding irrigation technology to use for rice farming. In this regard, farming household considers more than profitability to adopt irrigation technology as pointed earlier in the theories. Before adopting irrigation technology in particular cropping season, rice producing household considers things such as the resources to allocate in farming, quantity of rice to produce, quantity of rice to consume, quantity to demand from other market goods, external income to generate because these things have implications in the irrigation choice made. For instance, irrigation technology is costly, but farming household may still adopt given the household has external income to cover additional costs. Another example is that, if household consumes a lot from what it doesn't produce, this means the household will look for irrigation technology (i.e. SRI or TFIT) with possibility to produce more surplus rice that it will eventually sell to purchase other market goods to meet its consumption. That's a rationale of including variables like these in the model for such evaluation of choice determinants. These are distinctive things that rice producing household considers before adopting technology and they are extensively discussed in chapter three of this dissertation.

1.7 Organization of the Dissertation

The entire dissertation is organized into four chapters. The first chapter includes general introduction with important information on background and statement of the problem, study objectives, conceptual and theoretical framework. Chapter two presents paper number one that merge first and second objectives titled as economics of rice irrigation technologies in KSB. Chapter three presents paper number two which has been drawn from objective number three that addresses what a farming household considers in choosing rice irrigation technology in the study area. It should be noted earlier that although same methodology (sample location and sample size) has been applied in chapter two and three, each of them can be read as standalone paper. Chapter four gives general conclusions and recommendations.

References

Dinesen, L. (2017). Kilombero Valley Floodplain (Tanzania). pp. 1-8.

Eliya, J. (2016). *Effects of Flooding and System of Rice Intensification on Nitrogen*. Sokoine University of Agriculture. A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Master of Science In Soil Science And Land Management at Sokoine University of Agriculture, Morogoro, Tanzania. 65pp.

FCFA. (2021). *Climate change impacts – implications for policy and practice in Tanzania ' s Rufiji River Basin*.

Gowele, G. E., Mahoo, H. F., & Kahimba, F. C. (2020). Comparison of Silicon Status in Rice Grown Under the System of Rice Intensification and Flooding Regime in Mkindo Irrigation Scheme, Morogoro, Tanzania. *Tanzania Journal of Agricultural Sciences*, *19*(2), 216–226.

Hella, J., Sanga, G., Haug, R., Mziray, N., Senga, H., & Haji, M. (2020). Climate Change, Smallholders farmers' adaptation in Pangani Basin and Pemba. In *Implications for REDD+ Initiatives* (1st ed.). SUA. 34pp.

Höllermann, B., Näschen, K., & Tibanyendela, N. (2021). Dynamics of Human – Water Interactions in the Kilombero Valley, Tanzania : Insights from Farmers ' Aspirations and Decisions in an Uncertain Environment. *The European Journal of Development Research*,*3*(4),980–999. https://doi.org/10.1057/s41287-021-00390-4.

Kadigi, I. L., Mutabazi, K. D., Philip, D., Richardson, J. W., Bizimana, J. C., Mbungu, W., Mahoo, H. F., & Sieber, S. (2020). An Economic Comparison between Alternative Rice Farming Systems in Tanzania Using a Monte Carlo Simulation Approach. *Sustainability* , *12*,6528. https:// doi.org /10.3390/su12166528.

Kahimba, F., Sife, A., Maliondo, S., Mpeta, E., & Olson, J. (2015). Climate Change and Food Security in Tanzania: Analysis of Current Knowledge and Research Gaps. *Tanzania Journal of Agricultural Sciences*, *14*(1), 21–33.

Katambara, Z., Kahimba, F. C., Mahoo, H. F., & Mbungu, W. B. (2013). Adopting the system of rice intensification (SRI) in Tanzania: A review. *Agricultural Sciences,* Vol. 4 No.8, https://doi.org/10.4236/as.2013.48053

Makarius, L., Patrick, M., Yonika, N., & Chang'a, L. (2015). Understanding Watershed Dynamics and Impacts of Climate Change and Variability in the Pangani River Basin, Tanzania. *Ecohydrology and Hydrobiology*, 2015, 1–32.

Näschen, K., Diekkrüger, B., Leemhuis, C., & Seregina, L. S. (2019). Impact of Climate Change on Water Resources in the Kilombero Catchment in Tanzania. *Water 2019*, 11(4), 859. https://doi.org/10.3390/w11040859.

Ndabila, A. (2018). *Adoption of System of Rice Intensification and Impact on Yield in Mbarali District in Mbeya, Tanzania*. A Dissertation Submitted In Partial Fulfilment of the Requirements for the Degree of Master of Science In Agricultural Economics of Sokoine University of Agriculture. Morogoro, Tanzania. 96pp.

Negatu, W., & Parikh, A. (1999). The impact of perception and other factors on the adoption of agricultural technology in the Moret and Jiru Woreda of Ethiopia. *Elsevier Journal on Agricultural Economics, 21,* 205-216.

Ngwira, A., Johnsen, F.H., Aune, J.B., Mekuria, M., & Thierfelder, C. (2014). Adoption and extent of Conservation agriculture practices among smallholder farmers in Malawi. *Journal of Soil and Water Conservation, 69*(2), 107-119.

Olson, J., Alagarswamy, G., & Moore, N. (2015). *Analysis of the Impact of Climate Change on Crop and Water availability, and Consideration of Potential Adaptation Practices for the Rufiji River Basin, Tanzania*.

Soderberg, M. (2014). *Estimating Groundwater Availability and Variability in Kilombero Valley, Tanzania*. Stockholm University. 31pp.

Styger, E (2019). The System of Rice Intensification in Mali. *Alliance for Food Sovereignty in Africa*. Oakland Institute. Accessed through [https://afsafrica.org/wp-content/uploads/2019/04/sri_mali.pdf] site visited on 12/08/2022.

Upton, K., & Sanga, H. (2018). Hydrogeology of Tanzania. *Africa Groundwater Atlas*. [https://earthwise.bgs.ac.uk› index.php › Hydrogeolog] site visited on 15/08/2022.

URT. (2011). *Tanzania Agriculture and Food Security Investment Plan (TAFSIP)*. 75pp.

Wilson, E., McInnes, R., Mbaga, D. P., & Ouedraogo, P. (2016). *Ramsar Advisory Mission Report*. 85pp.

CHAPTER TWO

PAPER I

2.0 ECONOMICS OF RICE IRRIGATION TECHNOLOGIES IN KILOMBERO SUB-BASIN: A CASE OF FARMING HOUSEHOLDS IN KILOMBERO DISTRICT, TANZANIA

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2.1 Abstract

The System of Rice Intensification (SRI) irrigation is strongly emphasized by the Ministry of Agriculture (MoA) in Tanzania to replace Traditional Flooding Irrigation Technology (TFIT). SRI irrigation has been scientifically proven to be more efficient in water use over TFIT. SRI irrigation is therefore a good solution to approach climate change impacts that leads to water stresses, particularly in the country's water basins where rice farming is largely taking place. However, the economics of these irrigation technologies has not been evaluated at farming household level. The information on the economics of the two technologies is important in understanding why farming households are still using TFIT. Kilombero sub-basin (KSB) presents a compelling case for this study as 90% of irrigable land in the sub-basin is under TFIT. The study has used Net Revenue (NR) to evaluate profitability, and then multiple linear regressions to evaluate factors influencing profitability of the two irrigation technologies at household level. Results from the study have showed that an average Net Revenue (NR) of TZS 816 425 accrues to SRI irrigators, which is more than double of TZS 336 646 per acre that accrues to TFIT irrigators.

These benefits are obtained at different variable costs. Results have further showed that the aforementioned benefit from SRI had an Average Variable Cost of TZS 471 572, which is relatively higher than TZS 248 939 on acre under TFIT. Also results have showed that years spent in education, access to extension services, application of inorganic fertilizers and size of land allocated to rice production, are significant predictors of the profit to both technologies. Finally, the study has recommended the subsidization of inputs like fertilizers as well as placing more extension officers to areas found with inadequacy.

Keywords: Irrigation technologies, Net revenue and Farming household

2.2 Introduction

Increased water demand and reduced river flows due to Climate change impacts that have led to low rainfall are affecting Tanzania's 9 major basins (i.e. Pangani, Wami and Ruvu, Rufiji, Ruvuma and the Southern Coast, Lake Nyasa, Lake Tanganyika and the Lake Victoria and internal drainage such as Lake Rukwa Basin). Water quantity in many of these basins is reducing at an alarming rate. This effect is indicated by reduced water flow in the streams and rivers draining from these basins (Hella *et al*., 2020; Mutayoba, 2019; Näschen *et al*., 2019). As a result of reduced water flow, agricultural activities in these basins is of high risk making it vulnerable to climate change impacts on the basins., The most recent report by Wilson *et al.* (2017) in Kilombero sub-basin (KSB) have raised the concern on the future water availability in the basin. According to this report water in the basin will continue to decline over time, a situation that threatens the health of the sub-basin and its economic activities like irrigation agriculture.

To overcome the effects of reduced water flow in the sub-basin, it is deemed imperative to think on the way irrigation is done in area. Rice production being one of the major crops produced in the area that needs water, an effort to cope with this water stress caused by climate change effect is needed because water is decreasing in an area over time. Agricultural economics just like other economic studies is a study of choice making, it is therefore important to provide necessary economic insights to what is driving the choice of appropriate irrigation technology in KSB. Irrigation is one of the copying strategies to climate change impacts, however choosing an appropriate technology[1] is imperative to this climate change impacts copying strategy. Irrigation as a technology entails managerial approach of using water to grow crops in an area of low rainfall or extend production season where there is water

[1] Appropriate technology refers to a technology that is both water use and economically efficient.

However, as noted earlier the area is facing a reduced water flow because of little rainfall. Farming households in this area are faced with challenge of choosing an appropriate irrigation technology, the decision includes how water is used, whether flooding or controlled watering for plant growth (Mnyenyelwa, 2008; Amankwah and Egyir, 2013). Irrigation technologies for rice production in the sub-basin may be categorized into traditional flooding and SRI irrigation. Under the former technology, with exclusion of the period of controlling weed, constant pond water is maintained in the field until when drainage done for harvesting (Orasen *et al*., 2019). Meanwhile, the later technology involves minimum use of existing water through alternate wetting[2] and drying[3] the fields during the vegetative period of the plant (Katambara *et al*., 2013).

Scientifically, traditional flooding irrigation technology (TFIT) is mentioned to be the technique that uses large amount of water as it allows a lot of water to be lost through surface evaporation. Yet, the technology has low water productivity, implying low water use efficiency (Gowele *et al*., 2020). This is contrary to SRI irrigation, where it assures preciseness in providing plant with water in accordance with its requirement. This SRI irrigation technology has been proven agronomically to be relatively efficient in water usage (Kadigi *et al.*, 2020). Therefore, emphasis has been put especially by the Government of Tanzania (GoT) to convince farmers to shift from TFIT which is less water use efficient to SRI irrigation which is more water use efficient in KSB. Further, it is expected that farmers would switch from TFIT to SRI irrigation because of high efficiency water use. However, more than 90% of the sub-basin irrigable land is still under TFIT (Olson *et al*., 2015). This implies that more investigations need to be done on the two irrigation technologies that can be used in the sub-basin given the ongoing reduce water flow. Though from agronomic perspective it is clear that irrigation under SRI is water use efficient but it is not clear about its economics. Information on economic performance of the how rice irrigation technologies is important in designing appropriate

[2] Alternate wetting entails adding water into the field where rice plants are grown
[3] Drying means removing water out of field where rice plants are grown.

intervention policies to induce the shift (Musamba *et al*., 2011). Costs incurred and benefits accrued between SRI irrigation and TFIT will be additional information to policy makers besides the already known agronomic performance. Equally important, information on what determines profitability of these irrigation technologies is imperative to policy maker to introduce policies that will help shift from TFIT to SRI in the area. To achieve this, the study aimed at evaluating profitability and its determinants for both rice irrigation technologies practiced in KSB, using household as the unit of analysis.

2.3 Materials and Methods

2.3.1 Location and description of the study area

KSB is located in three districts namely Malinyi, Ulanga and Kilombero of Morogoro region that are found in Southern Central of Tanzania. The sub-catchment is suitable for production of a range of crops distributed according to the differences in micro climatic condition. Kilombero district is leading in rice production amongst the three districts that KSB extends. The district headquarter is situated in Ifakara town. Geographically the district is bordered with Mufindi district in the Northern part, Kilosa, Mvomero and Morogoro Districts to the East, Songea and Ulanga Districts to the South-East. According to URT (2022), the district has human population of 582 960 based on last census of 2022. The sub-basin has about 400 000 hectares of arable land of which rice production occupies more than 90% of the land (Wilson *et al*., 2017).

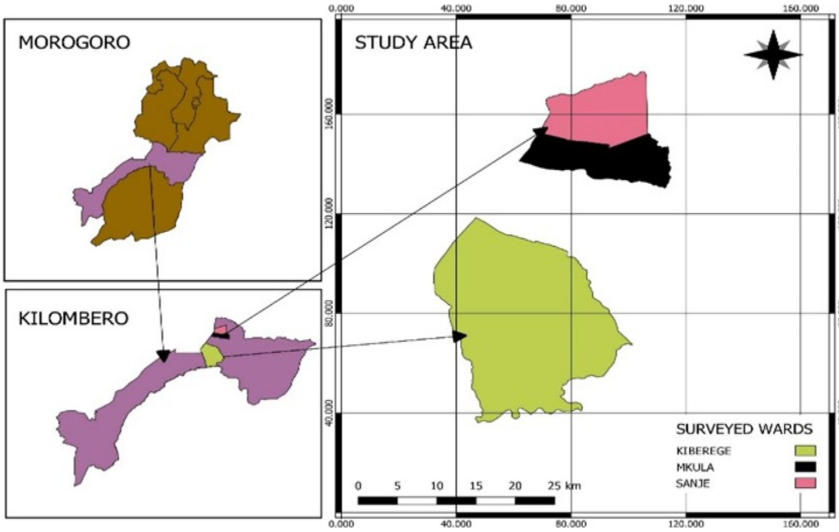

Figure 2.1: Map of Kilombero District showing surveyed villages

According to Mosha *et al.* (2016) and Alavaisha *et al.* (2021), Kilombero district has good infrastructures for SRI irrigation as there are major schemes like Msolwa Ujamaa, Mkula and Njage irrigation schemes with lined main canals that supply irrigation water to farm through small, secondary and tertiary canals. Existence of these main, secondary and tertiary canals in these schemes enables farmers in the schemes to easily do alternate wetting and drying which are key practices to adherence of SRI irrigation principles.

2.3.2 Data collection

Data for this study were collected from four villages purposefully selected from three wards. These included (1) Sululu village which found in Signal ward; (2) Mkula village which found in Mkula ward; (3) Sanje village which found in Sanje ward; and (4) Msolwa Ujamaa Village which is found in Sanje ward. The villages and the respective wards were purposefully selected basing on the existence of irrigation schemes using either SRI or traditional flooding.

Primary data were collected by using a face to face household survey using structured household questionnaires. The survey used stratified random sampling. The stratification was done to separate households using SRI irrigation from those using TFIT as two strata. Fifty households were selected from each stratum to make a total of 100 rice farming households. The size of the stratum chosen is based on the suggestion by Nkonoki (2015) that at least 30 representatives stratum is sufficient for socio-economic studies. Moreover, Sululu, Mkula, Msolwa Ujamaa and Sanje were respectively represented by 24, 25, 22 and 29 randomly selected rice producing households to make the sum of 100 rice farming households.

There is no precise date for population of farming households in Kilombero District as admitted in Key Informant Interview (KII) by head of agriculture department of the district. In addition, Mhoja *et al.* (2021) targeted same population for their study but they reported similar concern existing in the district. Therefore, that sample size of 100 rice producing households was considered enough for this study following the suggestion by McClanahan *et al*. (2005), that in absence of precise study population (like what happened in this study), the sample size of 80-120 respondents could be drawn to represent study population.

The study collected data on demographic and socio-economic characteristics of rice farming households, food security (quantity of rice consumed), income sources, labour days spent on rice production, quantitative information on production inputs used, rice harvest and prices of rice in different markets.

2.3.3 Analytical framework

Profitability of household engaged in production of irrigated rice in the study area was calculated considering value of all rice harvested (consumed or sold) by particular household. Farm budgeting method was used to calculate profitability as used by Ngaiza (2019) to calculate profitability of irrigated crop production.

Farm budgeting method enabled to compute[4] Net Revenue (NR) per acreage and individual farming terms.
For individual farming household, NR of traditional flooding and SRI irrigated area were calculated as follows:

$$NR_t^i = P_{rt}^i * RS_t^i - \sum \left(Q_{seed\,t}^i * P_{seed\,t}^i\right) + ¿\left(Q¿¿\,pesticide\,t^i * P_{pesticide\,t}^i\right) + \left(Q¿¿\,fertilizer\,t^i * P_{fertilizer\,t}^i\right) +$$

(1)

Where: NR_t^i = net revenue earned by farming household under technology *i* at time *t*, P_{rt}^i = market price of rice grown in technology *i* at time *t*, RS_t^i= total household rice under technology *i* at time *t*, $Q_{seed\,t}^i$= total quantity of seeds applied in technology *i* at time *t*, $P_{pesticide\,t}^i$= market price of pesticide used in technology *i* at time *t*, $Q_{fertilizer\,t}^i$ = total quantity of fertilizers used in technology *i* at time *t*, $P_{fertilizer\,t}^i$= market price of fertilizer used in technology *i* at time *t*, $MD_{labor\,t}^i$= total number of man-days used in technology *i* at time *t* and $W_{labor\,t}^i$= wage paid for man-days in technology *i* at time *t*.

Then a multiple linear regression model was specified to evaluate factors determine the profit under a given rice irrigation technology applied. This analytical method/technique was used to make an evaluation to address first and second specific objectives.

$$\pi_t^i = \beta_0 + \beta_1 Hlab_t^i + \beta_2 Hexp_t^i + \beta_3 FS_t^i + \beta_4 HYedu_t^i + \beta_5 EXvis_t^i + \beta_6 INcides_t^i + \beta_7 LQfert_t^i + \beta_8 GRANfert$$

(2)

Whereas π_t^i is the endogenous variable of profit realized by rice farming household in the technology applied 'i' in period t, while exogenous variables are $Hlab_t^i$ representing household labour provided in technology i in period t, $Hexp_t^i$ is the farming household experience in rice irrigation technology *i* in period *t*, FS_t^i

[4] Net revenue values are not discounted; they are just values from point analysis recorded in 2020/21 season

is farm size where irrigation technology i is applied in $period\, t$, $HYedu_t^i$ is the years in education of household head that applied technology i in period t, $\beta_5 EXvis_t^i$ is the number of extension visit that farming household in technology *i* has received in period t,$INcides_t^i$ is the number of insecticide litres that farming household in technology *i* has used at period *t*, $LQfert_t^i$ stands for quantity of liquid fertilizer that farming household in technology *i* has applied at period *t*, $GRANfert_t^i$ is the number of granular fertilizer kilogram that farming household in technology *i* has used in period *t*, $HHsex_t^i$ is the sex of household head that applied technology *i* in period *t* and CA_t^i stands for whether farming household applied technology *i* in period *t* borrowed credit or otherwise, FR_t^i stands for whether the sold rice from technology *i* at period *t* was threshed or not threshed, Vil_t^i represent the village that farming household resides at period *t*. β_0 β_1 β_2 β_3 β_4,β_5 ,β_6 , β_7,β_8 , α_1, α_2,α_3 , and α_4 are parameters estimated, where the first four are continuous and the last three parameters in the sequence are for dummies, ε represents error term.

2.4 Results and Discussions

2.4.1 Production costs in a given irrigation technology applied

The findings in Table 2.1 indicate that the average cost per acre incurred in managing soil fertility is relatively higher in SRI than traditional farming technology. This is because most of the farm plots under SRI are located in less fertile area than plots under traditional flooding. Results in Table 2.1 also show that the average labour service charge in SRI was TZS 322 594 which is higher than 171 682 observed in TFIT, this can be attributed to the fact that the two technologies differ in labour requirement. SRI is labour intensive than TFIT. The finding is consistent with what Kumar and Nayak (2013) found in India that SRI irrigation needs 50% more man-days than traditional irrigation to cover the added set of activities. Nonetheless, the cost incurred in purchasing pesticides is higher for SRI irrigation (TZS 18 164) compared to TFIT (TZS 9043.6) respectively.

This is attributed to the fact that SRI irrigation allows for pests to hide under the plant leaves while TFIT does not because of flooded water under the plant leaves. According to Dobermann (2004) pests hide in SRI irrigated fields since rice plants have less water under the leaves compared to TFIT.

Table 2.1: Production Costs

Variable (Costs in TZS)	SRI			Traditional flooding		
	Mean	**Min**	**Max**	**Mean**	**Min**	**Max**
Seed	14 854.67	0	300 000	6 883.3	0	45 000
Rent	44 066.67	12 320	200 000	40 667.3	6005	200 000
Granular fertilizer	68 142.8	0	240 000	19 047	0	120 000
Liquid fertilizer(booster)	3 750.0	0	42 000	1 616.67	0	14 000
Labour	322 594.3	64 450	666 666.7	171 682	32 210	615 000
Insecticide	18 164.0	0	120 000	9 043.6	0	97 142.9
TVC	471 572.5	64 450	1 018 333	248 939.9	32 210	950 000

Findings from Table 2.1 also reveal that, on average rent of land for agricultural purposes per acre in SRI was TZS 44 066 which was higher than 40 667 observed in traditional flooding. This implies most SRI farmers rented their land which is driven by the fact that SRI plots in the surveyed areas are found in irrigation schemes where most farmers rent plots on seasonal basis as buying cost is greater than convectional plots for TFIT found outside of the scheme. Generally, SRI had higher total variable cost (TVC) of TZS 471 572 than 248 939 in TFIT due to higher labour requirement and soil management of the former technology. Adding to that, Zero minimum cost in some inputs, implied that there were some farming households that did not incur any explicit cost particularly in fertilizers and insecticides probably due to failure to afford these agriculture inputs.

2.4.2 Net Revenue accrued to farming households

Results in Table 2.2 show that on average households who applied SRI and TFIT in 2020/2021 cropping season, recorded total NR of TZS 1 276 841 and 902 236 respectively and an average of TZS 816 425 and 336 646 per acre of SRI and TFIT respectively which generally indicate that almost all farming households engaging in rice production in both technologies were operating at profit.

More important is that SRI irrigation was found to be more profitable than TFIT due to controlled water usages that accelerates water productivity. This result is in consensus with the findings by Styger (2019) who found SRI irrigation to be twice more profitable than traditional flooding irrigation in Timbuktu, Mali. Implication drawn from total NR (TZS 1 276 841) in SRI irrigation is of at-least half of the current Tanzania GDP per capita. Therefore, even in the neglecting of other economic activities possibly undertaken by surveyed household heads, still farming households under SRI technology in the study area are not far from the threshold individual Tanzanian income.

Table 2.2: Net Revenue under the technologies applied

Variable	TFIT			SRI		
	Ave rage	Min	Max	Average	Min	max
Total NR	902 236	-277 000	4 377 000	1 276,841	-347 000	7 530 250
NR/acre	336 646	-144 666.7	1 682 000	816 425.9	-184 400	2 960 000

However, negative figures in minimum NR in both technologies has indicated that some farming households were operating at loss. Results have showed that a small number of households operated at loss with a minimal NR per acre of TZS -184 000 and –144 666 for SRI and TFIT respectively. SRI had smaller minimum NR over TFIT probably due to the fact that few farmers in SRI had no income to acquire the required pesticide on time. Also, based on finding by Kangile (2015), this undesirable return from their farming could be attributed by low yield that is further caused by low frequency of weeding and low experience in farming.

2.4.3 Determinants of profitability per technologies applied

Results in Table 2.3 have presented factors determining net revenue in TFIT and SRI from the multiple linear regression models. Results have showed that, explanatory variables specified in the model for TFIT and SRI successfully explained variation in the NR by 73.28% and 77% respectively derived from adjusted R-squares. From these results it has been observed that household head's years spent in schooling are positively related to profit accrued from traditional irrigation and SRI technologies. Results have showed that for each increment in a year spent in schooling by household head will increase the profit by TZS 39 163.09 and 75 793.58 for TFIT and SRI respectively. These imply that education has more substantial effect on understanding the scientific role of the technologies in question in increasing revenue accrued from the two technologies. This is built from the fact that SRI is the newly and scientifically recommended rice irrigation technology, it could thus be expected that more educated farmers could easily understand and apply the technology in efficient way over less educated people. This finding is consistent with observation of Ndabila (2018) who reported that more educated household heads are more risk taker than less educated, therefore, have less resistant to change towards new innovations.

Household experience in farming has a positive effect on profit accrued from both technologies. However, the effect was significant on TFIT and not significant SRI. Results in the Table 2.3 show that each increase in experience measured as years in practicing a given irrigation technology increase profit accrued by TZS 75 671.08 and -86 609 for TFIT and SRI respectively. Implication that is drawn from the finding is that an experienced farmer in TFIT is getting more profit compared to the experienced SRI adopter. Reasons for this is that experience goes with increase in farmer age, most SRI appliers were by far older than TFIT appliers, increase in years of experience makes increase in productivity and profit for TFIT farmer as he/she is still in productive ages meanwhile it causes no significant impact on SRI farmer profit as he has reached to the unproductive ages.

In furtherance, as it was initially expected, number of extension visits has positively associated with profit accrued by farming households of rice grown in both technologies. Provided that all other factors are held constant, every extension visit (be it farm visit or other visiting form) would cause a rise in profit level by TZS 101 695 for TFIT and TZS169 915 for SRI. The magnitude of relationship has showed that extension visits has bigger impact in profit for SRI irrigators compared to TFIT appliers. This is attributed to the fact that SRI irrigation needs extension service much more because of its technical and unique requirements unlike to the convectional rice irrigation. It is from this argument, farmer's access to extension service is deemed essential as through accessing the services they are exposed to good farm management practices like timely transplantation and controlled water usage. Nevertheless in both technologies more extension visits entails more profit as with high frequency in service, the farmers are also likely to manage risks like crop failures that jeopardize potential rice harvest and profit. This result matches with the finding by Kumar and Nayak (2013) who pointed out that reliable extension service is inevitable in generating profit of rice farming. Reported in different FGDs, villages like Mkula and Sululu were the victims of declining profit attributable to seldom extension visits meanwhile villages like Sanje and Msolwa Ujamaa appreciated the role that extension officers played in their good NR realized in the season.

In soil fertility management, profit was significantly increased by each unit (Kilogram) of granular fertilizer added in production process under TFIT, at the same time profit among SRI irrigators was significantly increased by each unit (litre) of liquid fertilizer added in farming. Similar findings are shared by Saweda *et al.* (2014) who confirmed that fertilizer application was found profitable on rice farming in Nigeria but cautioning efficient management practices in growing of the crop especially under convectional flooding technology. Equally important, Table 2.3 shows liquid fertilizers has more significant profitability in SRI irrigated farms while granular profitability is significantly realized in TFIT farms.

Table 2.3 however shows SRI has bigger change in profit of TZS 534 181 caused by a unit change in fertilizer compared to TFIT which is TZS 5145.787. This variation in fertilizer coefficients can be justified by the fact that SRI appliers were more knowledgeable and skillful in using fertilizers as they were very close to extension officers compared to TFIT irrigators.

Table 2.3: Regression results on profitability determinants under TFIT and SRI

Independent variables	Expected sign	NR under TFIT	NR under SRI
Household headship	+/-	-38 479.86(0.20)	34 539.3(0.12)
Household head years in schooling	+	39 163.09(2.11)**	75 793.58(2.12)**
Household head experience years in farming	+	75 671.08 (2.71)**	-86 609.44(1.32)
Form of rice sold	+	-251 564.7(1.04)	323 445.1(0.97)
Extension Visits	+	101 695.2(2.33)**	169 915.8(2.82)**
Credit borrowing	+	138 759.8(0.45)	595 989.9(2.10)*
Insecticides	+	-7 058.311(0.13)	-24 423.06(0.36)
Liquid fertilizer	+	101 750.7(1.22)	534 181(3.64)**
Granular fertilizers	+	5 145.787(2.00)*	2 556.79(0.78)
Village residing	+	215 894.3(0.87)	566 808.9(2.10)*
Land size	+/-	76 290.69(2.10)**	485 595.6(2.65)**
Intercept	+	-232 488.8(0.48)	-467 534.4(0.63)

** and * indicate Significance at 1% and 5% levels respectively.0.7328 and 0.7703 are the adjusted R-squared for the regression of TFIT and SRI NR respectively. T-values are on parentheses.

Furthermore, an acre increases in land size significantly has caused increase in net revenue by TZS 76 290 and 485 595 for TFIT and SRI irrigation respectively. Positive relationship between land size and profit in both irrigation technologies could be attributed to mode of land ownership that is common in the surveyed wards. Most farming households cultivate in the freely given plots of land through inheritance and government allotment. These farmers at large incur no explicit cost when add size of land during the season in question, thus they still get sales with grace of no explicit land acquiring cost. More important, Table 2.3 has revealed that SRI has higher net revenue over TFIT in each acre of land added in production because SRI technology requires more land due to its wider space between plants which is recommended under the technology. Therefore, given same amount of seeds and other inputs, increase in land size has been shown to have led more net revenue for SRI compared to TFIT. The finding which looks similar to what was reported by Kaloi *et al.* (2020) in Kenya and César *et al*.(2021) in Senegal that increment in land size led to higher increment in Gross Margin accrued by SRI adopters than TFIT users.

Location (village) in which farming household resided was also found significant to explain variation on profitability among farming households especially under SRI where holding other factors constant, households residing in Mkula ward were found to significantly earning higher NR than those residing in Msolwa Ujamaa by an average of TZS 566 808.9 difference. This locational difference in profit could be attributed by presence of advantageous infrastructures like huge rice milling plant (consider Appendix 4.2) in Mkula village that makes farming households in the ward to sell threshed paddy that from grain marketing perspective is expected be sold at higher prices due to value addition. In addition, profit differences between other two locations and Msolwa Ujamaa (reference group) are not discussed at this time because those differences were found to be not statistically significant.

2.5 Conclusion

This study has intended to evaluate the economics of TFIT and SRI rice irrigation technologies. The study firstly conducted profitability evaluation using NR, then evaluated what significantly determined profitability of rice under the two irrigation technologies. The findings showed that average rice production costs per acre were higher for SRI than TFIT, meanwhile Labour cost represented the highest expense incurred by farming households in both irrigation technologies. Also, the study found that both total and average Net Revenue per acre under SRI was higher than TFIT which finally implied that SRI was more profitable.

Further, results from the specified multiple linear regressions for SRI and TFIT profitability were found to be not far from what was anticipated earlier. For example, in soil fertility management, profitability was positively influenced by granular and liquid fertilizers for TFIT and SRI respectively. Moreover, extension service was another strong influencer of profitability in both technologies but with more profitability influenced in SRI irrigation. Also, an increase of household's land size owned for agricultural purposes was found to increase profit level of SRI irrigation compared to TFIT.

2.6 Recommendations

Subsidization to inorganic fertilizers could be viable option by the Ministry of Agriculture to benefit rice farmers in both technologies. This is based on substantial profitability that application of inorganic fertilizers has on respective technology. Therefore, if we really aim at getting more profit in KSB's rice farming, subsidizing more inorganic fertilizers could be good option. This is because farmers' access to this important agricultural input would increase and eventually rise in profit level accrued by farming households.

Rice producing households must change and make use of extension officers available in their areas, yet, the responsible ministry is obligated to recruit even more extension officers to be place in the villages with inadequacy like Sululu because reliability of extension service has been found to significantly increase profitability of both irrigation technologies in rice production.

Moreover, farmers and other interested stakeholders in rice subsector are encouraged to invest more land in KSB for SRI irrigation rather than other farming practices like TFIT. This is based from the finding that holding other factors unchanged, the bigger the land size devoted for SRI irrigation the bigger the profit is accrued.

References

Alavaisha, E., Mbande, V., Börjeson, L., & Lindborg, R. (2021). Effects of Land Use Change Related to Small Scale Irrigation Schemes in Kilombero Wetland, Tanzania. *Front. Environ. Sci.,* 9, 611686. doi: 10.3389/fenvs.2021.611686.

Amankwah, A., & Egyir, I. (2013). Modelling the Choice of Irrigation Technologies of Urban Vegetable Farmers in Accra, Ghana. *RePEc:ags:aaea,13,*149772 DOI: 10.22004/ ag.econ.149772.

César, D., Sambou, A., Ndiaye, O., & Seydou, D. (2021). Comparative Analysis of Rice Performance and Profitability with the System of Rice Intensification (SRI) and Traditional Practices (TP) in Ziguinchor District, Senegal. *Forestry & Agriculture Review*, *2.* 22-36. 10.47285/far.v2i1.64.

Diiro, G. M. (2013). Impact of Off-farm Income on Agricultural Technology Adoption Intensity and Productivity: Uganda Strategy Support Program, Evidence from Rural Maize Farmers in Uganda. *Agricultural Economics*, *2013,* 1–15. http://citeseerx. ist.psu.edu/viewdoc/summary?doi=10.1.1.303.3390.

Dobermann, A. (2004). A critical assessment of the system of rice intensification (SRI). *Agricultural Systems*, *79*, 261-281 https://doi.org/10.1016/S0308-521X(03)00087-8.

Eliya, J. (2016). *Effects of Flooding and System of Rice Intensification on Nitrogen*. Sokoine University of Agriculture. A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Master of Science In Soil Science and Land Management at Sokoine University of Agriculture, Morogoro, Tanzania. 65pp.

Gowele, G. E., Mahoo, H. F., & Kahimba, F. C. (2020). Comparison of Silicon Status in Rice Grown Under the System of Rice Intensification and Flooding Regime in Mkindo Irrigation Scheme, Morogoro, Tanzania. *Tanzania Journal of Agricultural Sciences*, *19*(2), 216–226.

Hella, J., Sanga, G., Haug, R., Mziray, N., Senga, H., & Haji, M. (2020). Climate Change, Smallholders farmers' adaptation in Pangani Basin and Pemba. In *Implications for REDD+ Initiatives* (1st ed.). SUA. 34pp.

Kadigi, I. L., Mutabazi, K. D., Philip, D., Richardson, J. W., Bizimana, J. C., Mbungu, W., Mahoo, H. F., & Sieber, S. (2020). An Economic Comparison between Alternative Rice Farming Systems in Tanzania Using a Monte Carlo Simulation Approach. *Sustainability*, *12*, 6528. https://doi.org/10.3390/su12166528.

Kaloi, F., Isaboke, H., Onyari, C., & Njeru, L. (2021). African Journal of Agricultural Research Comparing productivity of rice under system of rice intensification and conventional flooding. a switching regression approach. *African Journal of Agricultural Research*. *16,* 2019. 10.5897/AJAR2020.14921.

Katambara, Z., Kahimba, F. C., Mahoo, H. F., & Mbungu, W. B. (2013). Adopting the system of rice intensification (SRI) in Tanzania: A review. *Agricultural Sciences,* 4, 8, https://doi.org/10.4236/as.2013.48053.

Kumar, R., & Nayak, K. (2013), SRI 2013 New Method of Growing Rice. *Vikaspedia* [https://vikaspedia.in/agriculture/best-practices/sustainable-agriculture/crop-management/sri-2013-new-method-of-growing-rice/] site visited on 15/07/2023.

Mhoja, L., Mtae, H., & Haule, C. (2021). Levels of adoption of new rice farm management technologies among smallholder farmers in Kilombero District, Tanzania. *International Journal of Agricultural Policy and Research,* 9. 10.15739/IJAPR.21.020.

McClanahan, T., Davies, J., & Maina, J. (2005). Factors influencing resource users and managers' perceptions towards Marine Protected Area in Kenya. *Environmental Conservation,* 9, 283-298.

Mnyenyelwa, M. (2008). *Traditional Irrigation systems and livelihoods of smallholder farmers in Same District, Kilimanjaro, Tanzania.* A Dissertation Submitted in Partial Fulfilment of the Requirements for The Degree of Master of Science in Agricultural Economics of Sokoine University of Agriculture. Morogoro, Tanzania. 112pp.

Mosha, D. B., Kajembe, G. C., Tarimo, A. K. P. R., Vedeld, P., & Mbeyale, G. E. (2016). Performance of water management institutions in farmer-managed irrigation schemes in Iringa rural and Kilombero Districts, Tanzania. *Int. J. Asian Soc. Sci*., 6, 430–445. doi:10.18488/journal.1/2016.6.8/1.8.430.445.

Musamba, E. B., Ngaga, Y. M., Boon, E. K., Giliba, R. A., Sirima, A., & Chirenje, L. I. (2011). *The Economics of Water in Paddy and Non-Paddy Crop Production around the Kilombero Valley Ramsar Site, Tanzania : Productivity, Costs, Returns and Implication to Poverty Reduction*, *2*(1), 17–27.

Mutayoba, E. (2019). Uncertainity Reduction In Climate And Hydrological Models Predictions At Catchment Scale In The Upper Great Ruaha River Sub-Basin, Tanzania. A Thesis Submitted in Fulfilment of the Requirements for the Degree of Doctor of Philosophy of Sokoine University of Agriculture. Morogoro, Tanzania. 85pp.

Näschen, K., Diekkrüger, B., Leemhuis, C., & Seregina, L. S. (2019). Impact of Climate Change on Water Resources in the Kilombero Catchment in Tanzania. *Water 2019*, 11(4), 859; https://doi.org/10.3390/w11040859.

Ndabila, A. (2018). *Adoption of System of Rice Intensification and Impact on Yield in Mbarali District in Mbeya, Tanzania*. A Dissertation Submitted In Partial Fulfilment of the Requirements for the Degree of Master of Science In Agricultural Economics of Sokoine University of Agriculture. Morogoro, Tanzania. 96pp.

Ngaiza, H. (2019). Irrigation management transfer: Farmers' willingness to pay for operation and maintenance of selected improved smallholder irrigation schemes in Mbeya, Tanzania. Sokoine University of Agriculture.

Nkonoki, J. B. (2015). *Effects of institutional changes on forest condition: A case of Chenene Forest Reserve in Bahi District, Tanzania*. Unpublished Dissertation for Award of PhD Degree at Sokoine University of Agriculture, Morogoro. Tanzania. 66-67pp.

Olson, J., Alagarswamy, G., & Moore, N. (2015). *Analysis of the Impact of Climate Change on Crop and Water availability, and Consideration of Potential Adaptation Practices for the Rufiji River Basin, Tanzania*.

Orasen, G., Nisi, P. De, Lucchini, G., Abruzzese, A., Pesenti, M., Maghrebi, M., Kumar, A., Nocito, F. F., Baldoni, E., Morgutti, S., Negrini, N., Val, G., & Sacchi, G. A. (2019). Continuous Flooding or Alternate Wetting and Drying Di ff erently A ff ect the Accumulation of Health-Promoting Phytochemicals and Minerals in Rice Brown Grain. *Agronomy*, *2019*, 1–17.

URT (2022). Administrative Units Population Distribution Report. Dar es Salaam, Tanzania. Retrieved from https://www.nbs.go.tz/nbs/takwimu/Census2022/Administrative_ units_Population_Distribution_ Report_Tanzania_ volume1a.pdf] site visited on 15/09/2022.

Wilson, E., McInnes, R., Mbaga, D. P., & Ouedraogo, P. I. (2017). *Ramsar Advisory Mission Report*. 85pp.

CHAPTER THREE

PAPER II

3.0 INCREASING WATER DEMAND IN KILOMBERO SUB-BASIN DOWNSTREAM: WHAT UPSTREAM FARMING HOUSEHOLDS CONSIDER IN CHOOSING RICE IRRIGATION TECHNOLOGIES?

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3.1 Abstract

Climate change impacts are already experienced in the major basins in Tanzania, including Rufiji and Kilombero sub-basin (KSB), in particular. Water scarcity and demand by downstream users have also increased. As the result, new adaptative way of conducting agriculture has been induced. The system of rice intensification (SRI) irrigation has recently been encouraged in the sub-basin to withstand the impacts through controlled water usage under the system; however, 90% of rice irrigable land in KSB is still under traditional flooding irrigation technology (TFIT), the technology that exposes bulky of water to evaporation. This study has used reduced household models based on the fact that decisions for production and how to produce is made at household level by taking into account the household need for food, shelter, and other requirement. It has also considered that a farming household as decision unit meet its needs by purchasing from other households what they do not produce. Also the household decides on how to allocate resources at their disposal. From this understanding basin on utility and profit maximization theory, a household reduced model was developed to evaluate factors that motivate farming households to choose rice irrigation technologies. Some of the key findings from reduced household models include demographic characteristics like household headship and years spent education predicted land allocated for SRI irrigation. It was also found that Increase in rent leads to decrease in land allocated for SRI irrigation, instead farming household allocates land for TFIT. Market prices for rice had stronger negative influence on rice demanded by TFIT farming households than SRI group. Price for other market goods significantly affected SRI group more than TFIT group because SRI farming households were consuming very little of rice but more from market. Moreover, remittance availability was found influencing farming household to allocate land for SRI over TFIT. Finally, from these findings, the study recommends that government intervention through directing indicative rent for land is very important to induce the shift from TFIT to SRI irrigation. The diversification of income sources to cover new SRI costs is important for dissemination of SRI in the area. Also supporting services like credit facilities are highly recommended to help farming households to cover costs like additional man-days emanating from SRI irrigation.

Keywords: Sub-basin, irrigation technologies, Kilombero, farming household.

3.2 Introduction

The recharge of the major nine basins in Tanzania has recently become unpredictable due to its reliance on rainfall that is also unsteady in terms of the raining period (Sanga and Upton , 2018; Hella *et al*., 2020). Such rainfall unpredictability is attributed to climate change, which has caused water availability in these water basins to be affected (Makarius *et al*., 2015). Following these effects, the capacity of these water basins to support agricultural activities is projected to fall significantly. Projections indicate that the yield of crops like maize, sorghum, and rice will, on average, decline by 13%, 8.8% and 7.6 %, respectively in all the nine water basins by 2050 (Kahimba *et al*., 2015).

More specifically, Kilombero sub-basin (KSB) of Rufiji basin is one of the victims of climate change effects. The fact is braced by recent studies showing that the temperature in the sub-basin increases by 0.03°C annually, and rainfall, on the other hand, fluctuates between 500mm to 1500 annually (FCFA, 2021). Increasing temperatures increases surface evaporation and fluctuating rainfall causes uncertainty on the amount of rain and runoff in the streams and rivers recharging the sub-basin (Soderberg, 2014).

Despite the questionable future water availability in the sub-basin caused by climate change impacts, the sub-basin continues to be seen as an excellent reservoir for supporting human activities, including hydropower generation downstream (Höllermann *et al*., 2021). Julius Nyerere Hydropower Project (JNHPP) is of these human activities downstream. The JNHPP represents compelling investment that Government of Tanzania (GoT) has declared its importance as far as energy development is concerned. Equally important, 65% of water required for JNHPP comes from KSB (Ayo, 2022). Undeniably, reliable water supply for the investments downstream like JNHPP relies on other water uses upstream.

Irrigation farming is among human activities that are largely taking place upstream in the Kilombero sub-basin (Höllermann *et al*., 2021). One of the crops irrigated in the sub-basin is rice, which is water intensive, implying increasing demand for water in the sub-basin emanated from irrigation schemes initiated by the Ministry of Agriculture (MoA) to increase crop production countrywide (Näschen *et al*., 2019).

Furthermore, the increasing water demand could be triggered by rice irrigation technologies used in the sub-basin (Olson *et al*., 2015). Irrigation technologies like traditional flooding irrigation technology (TFIT) are scientifically mentioned to consume bulky water in rice irrigation as the technology allows more water to be lost through surface evaporation. To mimic water loss through surface evaporation, MoA introduced technologies that intensify water use by reducing water loss, namely, System of Rice of Intensification (SRI). One of the principles of SRI is controlled water usage. In principle, under SRI irrigation, it is assured that preciseness in providing the plant with water is per its requirement (Kadigi *et al*., 2020).

Following SRI's introduction, farmers are expected to switch from TFIT to SRI irrigation. However, more than 90% of the sub-basin irrigable land is still under TFIT(Olson *et al*., 2015). This entails that further investigation to understand factors hindering shifting from TFIT to SRI irrigation is essential. Given the fact provided by the literature, SRI has been better agronomically, especially in preventing the leaching of essential soil nutrients, as disseminated by Gowele (2020) and Eliya (2016). This study evaluates factors hindering the shift using an economic perspective by considering household aims to maximize utility and profits when making decisions. Notably, farming households often choose irrigation technology that maximizes profit and utility simultaneously.

Considering all these, the study incorporated farming households as a unit of analysis in evaluating factors constraining rice farmers in KSB from moving from traditional flooding irrigation to scientifically recommended SRI irrigation technology.

3.3 Kilombero Sub-basin

KSB lies between longitudes 34.563° and 37.797°E and latitudes 7.654° and 10.023°S. It presents a fascinating study area for empirical evaluation on the reasons why most farmers still irrigate under traditional flooding and not SRI. The sub-basin is very important in its ecology and hydrology to agriculture-based significance. The sub-basin continues to be extremely important in supporting crop cultivation and livestock keeping. For instance, commercial sugarcane production has expanded within Kilombero valley area from 3 500 ha in the 1990s to 15 000 ha in 2014 (Wilson *et al*., 2017). Besides sugarcane, the sub-basin is a significant rice-producing area, contributing almost 9% of all rice produced in Tanzania (Musamba *et al*., 2011). Moreover, GoT called for 40 000 ha of rice farming to stimulate economic growth in the area (Wilson *et al*., 2017), implemented through the designated Southern Agriculture Growth Corridor of Tanzania (SAGCOT). The SAGCOT programme is a public-private partnership that intends to attain fast and sustainable growth across a corridor of land extending from Dar es Salaam through Morogoro, Iringa and Mbeya to Sumbawanga close to the border with Zambia (Näschen *et al*., 2019).

Nevertheless, the sub-basin is threatened concurrently by; i) widespread and rapid conversion of the sub-basin into agriculture ii) Impacts of climate change on the sub-basin pronounced to occur. One significant implication of the latter threat is that agriculture practices aiming at enduring climate change impacts must be highly induced in the sub-basin. It is from this fact that slow shifting from TFIT to SRI irrigation is taken as a major concern threatening the sustainability of the sub-basin. This study collected data in representative areas of this sub-basin and used sampled farming households as the unit of analysis to disseminate the factors causing the reluctance of the shift.

3.4 Material and Methods

3.4.1 Location of the study area

This study was conducted in the Kilombero District of Morogoro region from June to July 2022. The district headquarters are mainly situated in Ifakara town which is 410 km away from Dar es Salaam. Geographically the district is bounded by Mufindi district in the Northern part, Morogoro District council to the East, Songea District council and Ulanga District to the South-East. According to URT (2022), the district has a human population of 582 960 based on the last national census of 2022. it occupies almost 400 000 hectares of arable land with rice largely grown, and the crop accounts for more than 90% of staple food consumed in the district (Wilson *et al*., 2017)

Specifically, data were collected in four villages (of three wards), namely 1-Sululu village in Signal ward (previously in Kiberege ward); 2. Mkula village in Mkula ward; 3. Sanje village in Sanje ward; 4. Msolwa Ujamaa Village in Sanje ward. The villages in the respective wards were purposefully selected following the existence of paddy irrigation schemes in these areas. More important, typical SRI irrigators could easily be approached for data collection since most farmers in these schemes are irrigating according to SRI principles, as reported during key informant interviews (KII) with the head of agriculture department in Kilombero district. These villages represent only rice irrigation schemes that are available in the Kilombero district.

3.4.2 Data collection

This study used both qualitative and quantitative data collection methods. The qualitative data collection method was applied to increase the depth and broad understanding of the research issue under consideration and smoothen the integration of results found.

Specifically, the study conducted three Focus Group Discussions (FGDs) in Sululu, Mkula and Msolwa Ujamaa villages. The participants in the discussions were the farming household heads. In collaboration with respective Village Executive officers, 15 participants (5 in each FGD) were purposefully selected based on their knowledge of rice farming. In addition, based on the knowledgeability one key informant (Head of agriculture department-Kilombero district) was purposefully chosen for an interview.

Quantitatively, primary data were largely used whereby face-to-face household survey was carried out using structured household questionnaires. The survey used stratified random sampling. The stratification was done per farm household under SRI irrigation and TFIT as two strata, 50 for each stratum, to make 100 farming households. In principle, Sululu, Mkula, Msolwa Ujamaa and Sanje were represented (randomly) by 24, 25, 22 and 29 farming households, respectively, to make 100 respondents.

3.4.3 Data analysis

The primary motive of this study is to evaluate factors that farming households consider in choosing rice irrigation technology to apply. The study started by deriving reduced farm household models to get drivers of various choices made by farming households from resource allocation and production to consumption in each irrigation technology. The derivation of reduced farm household models/equations was attributed to the fact that farming households were hypothesized to be joint producers and consumers of rice grain. It is from this fact that these models are strong in justifying how farming household decides on irrigation technology that maximizes both utility and profit at the same time (Singh *et al*., 1986).

Key assumptions were made before the derivation, such that the farm household sells and consumes the harvested rice and, equally important, the household purchases other goods from the market to meet its desired consumption. The model further assumes that a farm household depends on rice irrigation farming and other non-rice activities to generate income and maximize its consumption utility.

Specifically, the utility-maximizing problem is made up of Rice grain (X_G), market goods (X_M), Leisure hours (L_T) and household characteristics (φ) as follows,

$$Max\,U = U\left(XG, XM, <; \varphi\right) \quad (3)$$

Then a farming household needs irrigation technology to produce its rice (R_i), such that rice irrigation technology is either SRI irrigation or TFIT. But for this technology to produce rice grain, it relies on other exogenous variables as the production function, namely labour (L_i), resources endowed, e.g. land and water (δ), inputs purchased like seeds and fertilizers (YG_i) as well as irrigation technology parameter (α)

$$R_i = R_i\left(\alpha, L_i, YG_i; \delta\right) \quad (4)$$

The farming household can sell surplus rice in the market (R_i^s), then it faces rice balance (XH_i) of

$$XH_i = R_i - R_i^s \quad (5)$$

Normally, a farm household is limited in labour time (L_i). He has to allocate the time between rice production (Lr_i), non-rice producing activities (Lo_i) and leisure time (Lp_i); so, the household's constrained labour equation for any of the two technologies (since the variables on the right-hand side of the equation are the same in both technologies evaluated), it can thus be expressed as

$$L_i = Lr_i + Lo_i + Lp_i \quad (6)$$

It however should be noted that cash expenditures cannot exceed the total cash income, therefore encompassing income from non-rice activities (E_n); the household budget constraint can be expressed as follows

$$P_Y YG_i + P_M X_M \leq P_G R_i^s + Lo_i Wo_i + E \quad (7)$$

Where *E* stands for household's non-wage income; YG_i is the purchased number of inputs to make rice grain; P_Y, P_M and P_G are the prices of input, market good and rice, respectively. Also, Wo_i and Lo_i represent wage rate for non-rice producing activities and the number of labour hours spent in non-rice producing activities respectively. The decision problem for the consumption farm household will be to maximize the specified utility function (3) of particular irrigation technology subject to production, budget and time constraints established in (4) to (7) above. The Lagrangian for solution to this problem is then expressed hereunder

$$\mathcal{L} = U\left(XG, XM, <; \varphi\right) - \lambda_1\left(R_i - R_i\left(\alpha, L_i YG_I; \delta\right)\right) - \lambda_2\left(P_Y YG_i + P_M XM_i - P_G R_i^s - Lo_i Wo_i - E\right) - \lambda_3 (L \quad (8)$$

There are 9 decision variables to resolve from the model (8), namely $Lr_i; Lo_i; R_i; R_i^s; XM_i; YG_i; \lambda_1; \lambda_2; \lambda_3$. Thus, in order to obtain reduced form of equations required, 9 first-order conditions with respect to decision variables were derived (Appendix 3.1 – 3.9).

From the first order condition for optimization established above, reduced form of equations can ultimately be derived with decision variables showing all explanatory variables. Then these equations formed the basis for empirical estimation as done by other related studies like Sanga (2016) and Jogo (2010). Nine reduced form of equations would have been generated from the derived 9 first-order conditions for optimality, but in the case of this study, it was not necessary to generate all the equations instead only the equations that were conjectured to have factors influencing household decisions to irrigation technology were generated.

The decision variables evaluated in this study include the quantity of rice harvested by household under the technology applied (Rs_i), quantity of rice demanded by household (Rd_i), household demand for other non-market goods (Od_i) Household's external income (EY_i), household's land allocated to rice production (LR_i) and household's labour demand for rice production (Md_i) as follows.

$Rs_i = Rs_t$¿, Wo, β,α ,δ ,ε) (9)

$Rd_i = Rd_t$¿, Wo, β,α ,δ ,ε) (10)

$Od_i = Od_t$¿, Wo, β,α ,δ ,ε) (11)

$EY_i = EY_t$¿, Wo, β,α ,δ ,ε) (12)

$LR_i = Rd_t$¿, Wo, β,α ,δ ,ε) (13)

$Md_i = Md_t$¿, Wo, β,α ,δ ,ε) (14)

Where ε represents the error term and P_s denotes prevailing market prices for rice grain, input and market good.

Given that explanatory variables were the same, reduced household models (equation 9 to 14) were not estimated independently but rather in combination. The reason for not estimating the models individually is that error terms across the models could have correlated leading to biased and inconsistent estimates. It follows that Surely Unrelated Regression (SUR) was selected for this study to address any possible correlation between six equations. According to Jogo (2010) and Sanga (2017), SUR is very efficient in estimating system of equations jointly, at the same time it assures estimates of efficiency and unbiasedness because with SUR it was not expected to have correlated residuals across the equations. The appropriateness of selecting SUR in this study was justified by Breusch-Pagan test. This test was employed to confirm if there was no correlation between the residuals of different equations which were estimated jointly. From the test, chi-square was found to be 35.6 hence the use of SUR was confirmed as the chi-square was too big to justify that there was no correlation between the error terms.

This study has intended to evaluate what farming households consider in choosing irrigation technology in Kilombero district. To achieve this motive the reduced farm household models were run and the outputs are discussed hereunder.

3.5 Results and Discussions

3.5.1 Summary Statistics of the Variables Used in Econometric Analyses

Table 3.1 has presented descriptive statistics of the variables used in the econometric analysis. The statistics has showed that of the 100 households interviewed, 54% were male-headed. The average age of household heads is 46 years. Household size ranges from 1 to 11, with an average of 5 persons per household. Education levels in the study area are quite low; the average number of years of education of a household head is 8 years, which corresponds to primary education given that even years spent in nursery education are all considered. In addition, only 27% of household heads interviewed completed secondary education. In response, this finding answers another result found in the study area, that is, most households entirely depend on-farm activities. This can be shortened by stating that households in the area find themselves in the farming sub-sector alone, probably due to their low level of education that ultimately hinders them from getting formal employment.

Table 3.1: Descriptive for variables used

Variable	Mean
Household size	4.81
Household head level of education attained (years in schooling)	8.845
Age of household age (years)	46.71
Household labour size	2.91
Household head's farming experience (in years)	6.3
Rice quantity consumed (Threshed Kg/household/month)	27.71
Land size (acres)	2.255
Labour used in rice farming (days/household/season)	26.95
Rice retained for own consumption (threshed Kgs)	435.28
Yield of rice sold (threshed kgs)	1 350.82
Revenue from rice sales (TZS)	1 340 258
Net Revenue (TZS)	1 089 538
Extension access (number of extension officer visits/last two seasons)	3.33

3.5.2 Results from reduced household models

Table 3.2 has presented results from household reduce model showing factors influencing household decision in allocating resources to production of rice and the type of technology to use. As indicated in the conceptual framework that a household is considered as a decision unit in choosing the production technology to use and allocating resources at their disposal to various production ends and technologies. In this case the results show that the size of land owned by household significantly determined the amount of labour demanded for rice production. It is shown that an acre increment in the land owned by household would cause an increase of about 11 and 6 man-days per season for rice production under SRI and TFIT respectively. These figures reveal that as household land size increases, SRI technology demands more man-days than TFIT. This indicates that SRI is more labour intensive than TFIT, SRI involves additional activities from those under TFIT like alternate wetting and drying of land that require additional man-days of working on the field. According to Kumar and Nayak (2013), an increase in land size will cause the need for more man-days in SRI than TFIT.

Also, land owned for agriculture purposes has shown positive and significant impact to rice supplied by a particular household. Each acre increment in land size owned by household for rice production has caused an average increase of rice production of about 1180 and 262 kgs of threshed rice under SRI and TFIT respectively. Positive response in rice yield from land increase is also attributed to other factors other than land size increase such as good land management practices like fertilizer application and on time weeding. But more importantly is that a farmer practicing SRI is more important keen in observing these plant management practices than a farmer practicing TFIT and that is why there is more productivity under SRI than TFIT. In addition to these, farmers practicing SRI are more exposed to scientific and recommended way of growing rice than those who are practicing

TFIT. SRI comes with training package from extension officer on frequency of alternate drying and wetting, transplanting and planting spaces all that make rice plant to yield more. Similar findings are reported by Thakur *et al* (2023) in India that increase in size of land leads to higher increase in rice yield grown under SRI irrigation than TFIT.

Table 3.2: Factors influencing household decision on choice of rice production technology to use and resource allocation

	SYSTEMS OF RISE IRRIGATION (SRI)						TRADITIONAL FLOODING IRRIGATION TECHNOLOGY (TFIT)					
Variables	**Household land allocated to rice production**	**Labour demand rice production**	**Household quantity demanded for rice**	**Household quantity of rice supplied**	**Household quantity demanded of other market goods**	**Household external income**	**Household land allocated to rice production**	**Labour demand rice production**	**Household demand for rice**	**Household quantity of rice supplied**	**Household demand for other good**	**Household external income**
Household labour supply	0.234 (0.31)	1.061 (0.186)	0.534 (1.52)	2.012 (0.14)	0.052 (0.15)	2991.6 (0.29)	0.330 (0.91)	1.201 (0.912)	0.411 (1.43)	3.149 (0.48)	0.141 (0.88)	-618.5 (-0.13)
Household owned land size	0.632 (0.98)	11.466** (2.96)	-3.637 (-0.83)	1180.5** (5.77)	5.68 (0.87)	-0.109 (-0.56)	0.382 (1.11)	6.033** (2.89)	-0.336 (-0.15)	261.9** (5.10)	0.957 (0.58)	-9666.9 (-0.20)
Household size	0.591* (1.93)	3.535 (0.88)	2.191 (0.96)	190.2 1.46	4.691* (1.99)	103275 (1.11)	0.782** (3.27)	7.108 (0.98)	2.212441* (1.92)	61.692 (1.24)	2.144402 1.74	-119260.2 (-0.18)
Household head gender	0.678* (1.96)	0.021 (0.01)	3.614 (0.65)	-392.7** (-2.29)	8.714 (1.04)	152263** (2.68)	0.843** (2.31)	-3.071** (-2.67)	-6.169 (-1.03)	-211.2 (-1.17)	-2.396* (-1.99)	-28905** (-3.21)
Household head education years	-0.036 (-1.02)	-0.575 (-0.97)	-2.653** (-2.70)	72.76* 1.98	2.973** 2.42	131089** (5.35)	0.044 (0.68)	-0.353** (-0.57)	-1.560 (-1.91) *	-41.23* (-1.91)	2.352* (1.88)	34350.1* (1.96)
Experience years in rice farming	0.631** (2.93)	-1.782 (-1.21)	1.906 (1.47)	-162.8* (-2.09)	2.99 (0.51)	-39985* (-1.90)	0.777** 2.8	9.252 (1.27)	-0.585 (-0.64)	97.19 (4.36) **	0.533 (0.80)	-19897.3 (-1.98)
Market price of Rice	0.028 0.05	2.219 (0.82)	-0.623* (-1.82)	0.145 (0.02)	1.326* (2.69)	-3084.15 (-0.47)	0.044 (0.34)	1.025 (1.21)	-2.111** (-2.88)	1.821 (0.37)	-0.159 (-0.97)	-3465.73 (-0.95)
Land rent	-0.57* (-1.88)	-0.001 (-0.92)	-0.201 (-0.80)	-0.045 (-0.31)	0.163 (0.09)	1.267 (1.25)	-0.521 (-1.36)	-0.163 (-0.97)	0.022 (1.01)	-1.509 (-0.75)	-0.325 (-0.41)	-0.102 (-0.20)
Market price of seed	-0.109 (-1.41)	-0.201 (-1.41)	0.003 (0.31)	-8.216 (-1.04)	-0.285 (-0.42)	1120.763 (0.20)	-1.061 (-0.26)	-0.338 (-0.42)	-0.231 (-0.88)	-1.049 (-0.25)	-0.034 (-0.01)	-0.305 (-0.24)
Market price of fertilizer	-0.016 (-0.46)	-0.273 (-0.93)	0.004 (0.88)	-0.021 (-0.31)	0.145 (0.62)	4.480484 (0.89)	-0.551 (-0.99)	-0.039 (-0.89)	-0.828 (-1.42)	0.463 (0.85)	-0.912 (-0.06)	-0.074 (-0.57)
Market price of pesticides	-0.101 (-1.70)	-0.796 (-0.93)	-0.371 (-0.24)	-2.613** (-4.52)	-0.021 (-0.05)	1.327 (0.70)	-0.614 -1.68	-1.349 (-1.06)	-0.109 (-0.23)	-0.638 (-0.79)	0.008 (0.21)	-0.030452 -1.95
Household rice supply per season	0.53 1.30	0.2551 (0.14)	0.010 (0.04)		-2.113 (-1.21)	-4.347 (-0.70)	0.001 0.95	0.019 (0.48)	0.020 (0.37)		-0.422 (-1.33)	0.004 (0.22)
Market prices for other market	-0.86 (-0.91).	0.034 (1.11)	0.973 (0.21)	0.635 (1.09)	-2.667* (-1.33)	1895.1 (1.11)	-0.011 (-0.68)	0.347 (0.97)	1.211 (1.02)	0.998 (1.22)	-3.579 (-1.41)	0.034 (0.23)
Remittances	0.931** (2.33)	-0.912 (-0.89)	0.112 (0.67)	20.333 (0.98)	3.472 (4.91)	75670 (1.40)	0.667* (1.94)	-1.561 (-0.96)	1.132* (2.89)	18.561 (1.76)	8.632 (0.56)	18450.0 (0.89)
Constant	0.301 (0.40)	17.742 (0.57)	-2.186 (-0.11)	196.8 0.17	- 56.55125 -1.93	513998.6 (0.66)	-0.054 (-0.03)	17.22 (1.13)	39.804* (2.02)	389.35 (0.63)	2.995648 (0.21)	672478 (1.46)

Values in the parentheses show z-statistics where ** and *denotes variables significant at 5% and 10% significant levels

As expected, household size has also a very strong influence on household's demand for rice as food and other market good. Table 3.2 has showed that as one member is added in the household; demand for rice food would increase by 2.21 Kgs which is statistically significant to households practicing TFIT and demand for other market good will increase by 4.69 Kgs which is statistically significant to households practicing SRI. These concur with previous results that household practicing SRI earn more income that those practicing TFIT which make them to have a capacity to buy other food products they prefer other than rice. This is quite the opposite of households practicing TFIT, they earn less income than their colleagues practicing SRI; therefore, they have to rely on what they produce which is rice. There is close similarity between in this finding with what was reported by Ramdhanie *et al.* (2017) in North Trinidad, that household size positively determining quantity of food and other market goods demanded by smallholder farmers as they are more interested in quantity than quality of food.

Moreover, in household head gender, results have indicated that households headed by males allocate more land for rice production than female in both technologies. This can be attributed to the fact that in study area land ownership is gender biased; males are the owners of land and hence they are ones who make the final decision on how to allocate land for rice production. From focus group discussion it was revealed that males headed households who practice TFIT own land than household practicing SRI. This can be attributed to the fact that SRI is a newly introduced technology and is labour intensive, only those with small plots are going for it in order to maximize profit as it has high promising profit. Equally important, renting a plot under SRI is very expensive than a plot under TFIT and in most cases SRI is largely practiced in irrigation schemes. This finding is a bit contrary to conclusion made by Das *et al*. (2022) in India that land allocated by women to SRI irrigation was larger over men due to entitlement of more assets to Indian women than men.

Equally important, in both technologies pertaining to rice supply, female headed households on average outshined male headed households by supplying more rice. Possible explanation for this is that females are pronounced to be relatively more into farming activities for the purpose ensuring food security to their families. Nonetheless, gender effect to quantity of rice supplied was not significant to households practicing TFIT probably due failure of female farmers to follow proper agronomic practices. This implies that extension services in the area are gender biased. Better yield of rice in female headed households than male headed ones was also reported by Thabiti (2014) who conducted a study in Kyela-Mbeya. Furthermore, gender was found to be an issue when it comes to external income, female headed households were found to earn less external income compared to male headed households under SRI. This can be attributed to the fact that SRI is labour intensive, females have to devote much of their time on farm works than other economic activities, hence earning less from these sources of income. However, the situation is different under TFIT, female headed households earn more external income than male headed households because TFIT is less labour intensive, thus female household heads have more time to engage in off-farm economic activities hence get more external income.

Education was found statistically significant in influencing household rice farming decisions. Results from Table 3.2 have showed that education predicted the external income that farming households were accruing. As expected, years spent in education showed positive contribution to external income generated by farming household. This is because having more education means household head is more likely to get job outside farming activities, hence there would be increase in external income accrued by farming household resulted from paid salaries. In addition, each increment in years spent in education by household head will lead to an average increase of external income by TZS 131 089 and 35 380 for SRI and TFIT groups respectively. Similar result was obtained by Tran *et al.* (2023) in Thailand and Vietnam that increase in farmer's years spent in education went with increase in external income generated *Ceteris Paribus*. This study in question however found that SRI farmers' external income is more elastic to change in education years probably because they are more rational to grab external opportunities to get extra income. Finally, SRI farming households probably are in relatively higher need of extra income than TFIT ones because SRI farmers need to cover new farming expenses (highlighted earlier) which are not incurred by TFIT farmers.

Furthermore, demand for rice as food was also found indirectly being influenced by education through external income elaborated above. It was found that as household head gets more education, even demand for rice food falls among households by 2.7kgs (SRI) and 1.5 kgs (TFIT). Education was probably found determining quantity of rice demanded through the issue of external income. As highlighted above, increasing years in education means more external income to farming household. In this sense, ability of household to afford non-rice foods might increase because of the income increased. More important is that given any increment in education years by household head, demand for rice falls more in SRI households than in TFIT households probably because most SRI households attained higher education levels compared to their colleagues in TFIT.

Education also was found to predict the amount of rice a farming household supply to the market per season. Each increment in years spent in education caused positive effect of about 72.76 kgs of rice from SRI and negative effect of about 41.23 kgs of rice from TFIT. This is because SRI irrigation requires more knowledge and educated households are more likely to acquire it quickly than less educated. Furthermore, the negative effect on rice supply shown by education TFIT indicates that most of the households practicing TFIT are less educated and hence they have low productivity which makes them not to be able to produce surplus to supply to the markets. Similar findings are reported by Tusekelege *et al.* (2014) who conducted their study in Dakawa, Morogoro and pinpointed the significance of education in explaining productivity of SRI irrigation among surveyed farmers.

Equally important, education has showed positive contribution to household demand for other market goods. Specifically, years spent in education positively contributed to quantity demanded of other market good such as food among farmers in both SRI and TFIT. An increment in education years would cause an increase of 3 and 2Kgs of other food demanded by households in SRI and TFIT respectively. The observed differences are because households practicing SRI were more educated than those practicing TFIT. Equally important, as noted earlier educated households have more opportunities to earn external income than less educated, making them able to afford more other markets goods compared to their counterparts, so the difference in the effect is also attributed to this fact. Moreover, Miassi *et al.* (2022) had also similar observation in West Africa that as farmer gets educated, his/her demand for market goods increases holding other things unchanged due to increased awareness on dietary foods.

Experience of a household head in farming also was found to influence household's decisions to land allocated, rice supply and external income. Table 3.2 shows that experience in rice farming influence positively the allocation of land for rice production. The results showed that the more experienced the farmer, the larger the land allocated for rice farming. Results show that the more the experience the farmer has the less the land is allocated to SRI (0.63 acre) compared to land to TFIT (0.78 acre). According to Kasase *et al*. (2022), this can be attributed to the observation that SRI is a relatively newer technology and people have no much experience as compared to TFIT, hence more land is allocated to TFIT than to SRI production technology.

Moreover, experience in rice farming influenced negatively households practicing SRI and positively households practicing TFIT in rice supply. Each increment in years of experience may cause a decrease of about 162 Kgs in rice supply from households practicing SRI and an increase of about 97 Kgs of rice from households practicing TFIT supply. Meaning that in a long-run more experienced rice farming households will shift to TFIT since the technology is less labour intensive, hence less production costs as compared to SRI. Thus there is contradiction of this finding and that of Karki *et al.* (2019) where farmers with more experience are more likely to go for climate change resilient technologies like SRI irrigation which offers higher produce. Such inconsistency of finding is probably because their study was too generic to observe site specific findings like of KSB.

Findings from Table 3.2 has indicated that as experience years in farming increases, external income for farming household decreases. This is because in a short-run, farming household will decide to keep on rice farming rather than going for off-farm economic activities to get external income as also reported by Layani *et al.* (2020) in Marvdasht County, this however may change in long-run when a farmer is getting even older, he/she may switch to off-farm economic activities. Therefore, increase in experience years may lead to increase in external income in a long-run. Market price of rice was found statistically significant in explaining variation in household demand for rice food and demand for other market goods. Table 3.2 showed that a unit price increase in rice would cause a decline of quantity demanded for rice by 0.623 and 2.11 kgs from SRI and TFIT among farming households. This negative relationship between price and quantity demanded of rice in both groups is consistent with the demand theory for any rational consumer (Mankiw, 2016). The increase in rice price led to decline in quantity demanded for rice food in the farming households belonging to both irrigation technologies. However, the degree of responsiveness in quantity demanded between the households in two groups differ. Such difference might be attributed to the fact that, unlike to SRI farmers, rice is the leading staple to TFIT farmers, a unit change in price of rice might have led to larger change in rice quantity demanded in farmers belonging to TFIT than SRI. There was small change in rice quantity demanded for SRI farmers because they consumed less of rice and more of other market good, so they are less affected by rice price changes.

Nonetheless, Table 3.2 has showed that land rent has a significant negative effect to both technologies. As land rent increases, SRI and TFIT farming households decide to reduce land allocated to each technology by 0.6 and 0.5 acres respectively. This negative relationship is attributed to the fact that price for land in irrigation schemes is relatively higher than outside the scheme where TFIT is largely applied. Given the same increase in land rent, farming households practicing SRI are affected more than households' practicing TFIT. This is why households practicing SRI reduce more the area allocated to rice that households practicing TFIT. Largely, this finding agrees with report by Qui *et al.* (2020) that the increase of land rent reduced land acres allocated for modern rice production in Rural China.

Equally important, remittance was found to be significant predictor of decision to allocate land for rice farming among household heads. Table 3.2 showed that remittance and land allocated for rice production had positive relationship, whereby as remittance increases, land allocated for rice production increases because remittance increases an ability of farming household to cover land acquisition expenses. More important, farming households in TFIT group (1.13 acre) was found to be more benefiting by an increase in remittance on land allocation compared to those in SRI (0.93 acre). This can be attributed to the fact that SRI plots are a bit more expensive to acquire hence given same increase in remittance, SRI households can afford to acquire relatively smaller land in irrigation scheme compared to their colleagues (TFIT households) who acquire plots with cheaper payments.

3.6 Conclusions

The motive of this paper has been to evaluate how farmers arrive at choosing rice irrigation technology in Kilombero district. To achieve this objective, household reduced equations were derived to understanding how household heads come to decide the irrigation technology to use. The results from this research are vital in understanding the reasons to why most rice farmers in the KSB are yet to move from TFIT to the latest SRI irrigation technology.

Results from household reduced models have showed that demographic characteristics like household head's years spent in education and gender were most influential in determining various decisions like land allocation and labor supply to irrigation technology. Nevertheless it was found that education more contributed decision in favor of SRI irrigation than TFIT, but SRI irrigation was found to be more labor intensive than TFIT, hence the continuation of farming households with TFIT. Household head experience in farming was influencing decision in favor of TFIT than SRI irrigation.

Generally from the findings, low education has made farming household in the studied sites found in KSB to continue with TFIT. Socially, men were found being in bigger chance to accept SRI irrigation since they have more pre-requisite resource for practicing SRI irrigation, particularly, they are more entitled to land ownership and allocation than women. Also, labor intensity nature of SRI has triggered many farming household in KSB to continue practicing TFIT. Further, farming households in the surveyed areas are still using TFIT because they face shortage of income especially from off-farm economic activities to cover additional costs arising in SRI.

3.7 Recommendations and Policy Implications

i. The key policy implication from these results is that government intervention through directing indicative rent for SRI plots is very important to induce the shift from TFIT to SRI irrigation.
ii. Also, the newly introduced technologies like SRI should be incorporated in agriculture related subjects or even topics taught in primary schools to make this young generation familiar of the technology earlier.
iii. Adding on that, information on diversified sources of income should be provided to the farming households because through external income farming households can probably afford SRI that has been found relatively more costly than TFIT, hence more adopters of SRI irrigation
iv. SRI irrigation is more labor intensive than TFIT due to the added activities like alternate wetting and drying, this calls for more research and development (R&D) by Tanzania

v. Agricultural Research Institute (TARI) with rice as their mandate crops (TARI-Dakawa and TARI-Ifakara) to experiment and disseminate the technologies with minimal labor requirement in SRI irrigation.

vi. Finally, extensive campaigns should be done in the studied sites by gender development practitioners with an emphasis to increase women entitlement to resources like land since women might be willing to practice SRI irrigation but they get no irrigable land for rice production as such entitlement is largely held by men.

References

Ayo, M. (2022). Drone Julius Nyerere Hydropower Plant and Dam - Tanzania. Julius Nyerere Hydropower Plant and Dam - Tanzania [https://www.arabcont.com › English › project-596] site visite on 12/09/2022.

Das, L.,Mishra, S.,Pattanaik, S.,Panda, P & Panda, R. (2022). A Case Study on Gender Differentiated Role Analysis in Rice Farming in a Rice Intensive Ecology. pp. 707-714.

Eliya, J. (2016). *Effects of Flooding and System of Rice Intensification on Nitrogen*. Sokoine University of Agriculture. A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Master of Science In Soil Science And Land Management at Sokoine University of Agriculture, Morogoro, Tanzania. 65pp.

FCFA. (2021). Climate change impacts – implications for policy and practice in Tanzania' s Rufiji River Basin. 16pp.

Gowele, G. E., Mahoo, H. F., & Kahimba, F. C. (2020). Comparison of Silicon Status in Rice Grown Under the System of Rice Intensification and Flooding Regime in Mkindo Irrigation Scheme, Morogoro, Tanzania. *Tanzania Journal of Agricultural Sciences*, *19*(2), 216–226.

Hella, J., Sanga, G., Haug, R., Mziray, N., Senga, H., & Haji, M. (2020). Climate Change, Smallholders farmers' adaptation in Pangani Basin and Pemba. In *Implications for REDD+ Initiatives* (1st ed.). SUA. 34pp.

Höllermann, B., Näschen, K., & Tibanyendela, N. (2021). Dynamics of Human – Water Interactions in the Kilombero Valley , Tanzania : Insights from Farmers ' Aspirations and Decisions in an Uncertain Environment. *The European Journal of Development Research*, *33*(4), 980–999. https://doi.org/10.1057/s41287-021-00390-4.

Jogo, W. (2010). *Managing the trade-off between conservation and exploitation of wetland services for economic well-being : The case of the Limpopo wetland in southern Africa By Wellington Jogo PhD Environmental Economics*. University of Pretoria.175pp.

Kadigi, I. L., Mutabazi, K. D., Philip, D., Richardson, J. W., Bizimana, J. C., Mbungu, W., Mahoo, H. F., & Sieber, S. (2020). An Economic Comparison between Alternative Rice Farming Systems in Tanzania Using a Monte Carlo Simulation Approach. *Sustainability* , *12*, 6528. https://doi.org/10.3390/su12166528

Kahimba, F., Sife, A., Maliondo, S., Mpeta, E., & Olson, J. (2015). Climate Change and Food Security in Tanzania: Analysis of Current Knowledge and Research Gaps. *Tanzania Journal of Agricultural Sciences*, *14*(1), 21–33.

Karki, S., Burton, P., & Mackey, B. (2020). The experiences and perceptions of farmers about the impacts of climate change and variability on crop production: *a review, Climate and Development*, *12*(1), 80-95, DOI: 10.1080/17565529.2019. 1603096

Kasase, H., Shija, B., Kumar, S., & Kangile, J. (2022). Measuring the intensity of adoption of the system of rice intensification and improved rice seeds technologies in Geita district, Tanzania: *A International Journal of Statistics and Applied Mathematics*, 7(5): 83-93.

Kumar, R., & Nayak, K. (2013), SRI 2013 New Method of Growing Rice. *Vikaspedia* [https://vikaspedia.in/agriculture/best-practices/sustainable-agriculture/crop-management/sri-2013-new-method-of-growing-rice/] site visited on 15/07/2023.

Layani, G., Bakhshoodeh, M., & Ahmadikia, Z. (2020). Determinants of Farmers' Participation in Off-farm Activities and its Impact on Income Equality in Marvdasht County. *Journal of Agricultural Economics and Development, 34.* 259-273. 10.22067/jead2.vi0.81683.

Makarius, L., Patrick, M., Yonika, N., & Chang'a, L. (2015). Understanding Watershed Dynamics and Impacts of Climate Change and Variability in the Pangani River Basin, Tanzania. *Ecohydrology and Hydrobiology*, *2015,* 1–32.

Mankiw, N. G. (2016). *Principles of microeconomics* (8th ed.). CENGAGE Learning Custom Publishing.526pp.

Miassi, Y. E., Dossa, F. K., & Zannou, O. (2022). Socio-cultural and economic factors affecting the choice of food diet in West Africa: a two-stage Heckman approach. *Discov Food, 2,* 16. https://doi.org/10.1007/s44187-022-00017-5.

Musamba, E. B., Ngaga, Y. M., Boon, E. K., Giliba, R. A., Sirima, A., & Chirenje, L. I. (2011). *The Economics of Water in Paddy and Non-Paddy Crop Production around the Kilombero Valley Ramsar Site, Tanzania: Productivity, Costs, Returns and Implication to Poverty Reduction*, *2*(1), 17–27.

Näschen, K., Diekkrüger, B., Leemhuis, C., & Seregina, L. S. (2019). *Impact of Climate Change on Water Resources in the Kilombero Catchment in Tanzania. Water 2019,* 11(4), 859; https://doi.org/10.3390/w11040859.

Okello, D. M., Bonabana-Wabbi, J., & Mugonola, B. (2019). Farm level allocative efficiency of rice production in Gulu and Amuru districts, Northern Uganda. *Agric Econ, 7,* 1-19. https://doi.org/10.1186/s40100-019-0140-x.

Olson, J., Alagarswamy, G., & Moore, N. (2015). *Analysis of the Impact of Climate Change on Crop and Water availability, and Consideration of Potential Adaptation Practices for the Rufiji River Basin, Tanzania*.

Qiu, T., Choy,S., Li, S.,He,L & Luo, B. (2020). Does land renting-in reduce grain production? Evidence from rural China. *Land Use Policy*, Volume 90, https://doi.org/10.1016/j. landusepol.2019.104311.

Ramdhanie, V., Pemberton, C & Granderson, I. (2017). Socio-economic factors affecting household food expenditure in North Trinidad. *Trop. Agric. (Trinidad)*. 2017, 1-17. https://doi.org/0041-3216/2017/010020-11.

Sanga, G. J., & Mungatana, E. D. (2016). Integrating ecology and economics in understanding responses in securing land-use externalities internalization in water catchments. *Ecological Economics*, *121*, 28–39. https://doi.org/10.1016/j. ecolecon.2015.11.011.

Singh, I., Squire, L., & Strauss, J. (1986). A survey of agricultural household models: Recent findings and policy implications. *The World Bank Economic Review*, *1*(1), 149-179.

Soderberg, M. (2014). *Estimating Groundwater Availability and Variability in Kilombero Valley , Tanzania*. Stockholm University.

Thabiti, T. (2014). Gender Analysis in Rice Production in Kyela District, Mbeya Region-Tanzania. A Dessertation Submitted in Partial Fulfilment of the Requirements for the Degree of Master of Arts in Rural Development Ofsokoineuniversity of Agriculture.Morogoro,Tanzania. 74pp.

Thakur, A. K., Mandal, K. G., Verma, O. P., & Mohanty, R. K. (2023). Do System of Rice Intensification Practices Produce Rice Plants Phenotypically and Physiologically Superior to Conventional Practice? *Agronomy*, *13*, 1098. https://doi.org/10.3390/agronomy13041098.

Tran, D., Pham, T & Nguyen,T. (2023). Education and agricultural household income: Comparative evidence from Vietnam and Thailand, World Development Perspectives. *Elsevier, vol. 29(C)*. https://doi.org/10.1016/j.wdp.2023.100489.

Tusekelege, H., Kangile, R. J., Ng'elenge, H. S., Busindi, I.M., Nyambo, D.B & Nyiti, E. (2014). Option for Increasing Rice Yields, Profitability, and Water Saving; A Comparative Analysis of System of Rice Intensification in Morogoro, Tanzania *International Journal of Recent Biotechnology,* 2014, 1-9.

Upton, K., & Sanga, H. (2018). Hydrogeology of Tanzania. *Africa Groundwater Atlas*. [https://earthwise.bgs.ac.uk › index.php › Hydrogeolog] site visited on 15/08/2022.

URT (2022). Administrative Units Population Distribution Report. Dar es Salaam, Tanzania.Retrievedfromhttps://www. nbs.go.tz/nbs/takwimu/Census2022/Administrative_units_ Population_Distribution_Report_Tanzania_volume1a.pdf] site visited on 15/07/2022.

Wilson, E., McInnes, R., Mbaga, D. P., Ouedraogo, P., & I. (2017). *Ramsar Advisory Mission Report*. 85pp.

CHAPTER FOUR

4.0 SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS

4.1 Conclusion of the Key Findings

This study has intended to evaluate the economics of rice irrigation technologies and evaluating how farmers arrive at choosing rice irrigation technology in Kilombero district. To achieve this objective, household is chosen as the unit of analysis. Then the study has used Net Revenue (NR) and its determinants to evaluate the economics of traditional flooding and SRI irrigation technologies, this is first part of this study. Secondly, household reduced equations were derived to understand how household heads come at deciding the irrigation technology to use. The results from this research are vital in understanding the reasons to why most rice farmers in Kilombero sub-basin are yet to move from TFIT to the latest SRI irrigation technology.

SRI and traditional irrigation technologies were first analyzed in terms of costs, revenue and finally profitability. In production costs SRI had relatively higher cost than TFIT, with cost of hiring labour represented highest expense among other production costs like agriculture input purchases. In profitability, on average SRI irrigators earns higher net revenue per farming household compared to those in TFIT. Adding on that, farming households in SRI were found to be earning relatively higher net revenue per acre compared to TFIT. This generally showed that in the aspects evaluated in this study, SRI irrigation was more profitable than TFIT.

Results from the specified multiple linear regressions for SRI and traditional flooding technologies have been found to be not far from what was anticipated earlier. The profitability of both TFIT and SRI was positively and significantly influenced by farming experience, farm size, soil fertility management and support services like borrowing and extension. Specifically, the use of granular fertilizer was more influential to TFIT profitability and liquid fertilizer to SRI profitability. Furthermore, in second part of study which is about choice determinants for rice irrigation technology, results from farm reduced equations have indicated that farming households in KSB consider many things before deciding to accept or not accepting rice irrigation technology to use in a particular cropping season. Specifically from the findings, Education of a household head also emerged as one of the factors influencing decision between the two technologies; households headed by an educated household head preferred SRI more than TFIT. Thus, low education has made farming household in the studied sites found in KSB to continue with TFIT.

Also, labor intensity nature of SRI has triggered many farming households in KSB to continue practicing TFIT. It was revealed through this study that households consider the opportunity cost time across various economic activities at their disposal. In choosing the type of technology to use labor time emerged as the major concern of households. Many households preferred TFIT more than SRI because of labour requirement

Further, external income also emerged as one of the key factors. Farming households in the surveyed areas are still using TFIT because they face shortage of income especially from off-farm economic activities to cover additional costs arising in SRI. Hence, households engaging more in activities other than rice farming preferred SRI than TFIT implying that they have income to invest in SRI which is more profitable than TFIT

Socially, men are found being in bigger chance to accept SRI irrigation since they have more pre-requisite resources for practicing SRI irrigation, for example it was found that men are more entitled to resource ownership and allocation than women. Experience was another factor that emerged as one of the key factors in influencing household decision; households headed with an experienced household head preferred TFIT more than SRI indicating that they are more concerned of labor requirement as cautioned earlier.

Generally, from two parts of this study, the study found that even though SRI is labour intensive it is economically profitable than TFIT. Equally important, SRI is less water demand and it helps in reducing water loss through surface evaporation

4.2 Policy Implications and Recommendations

i. Policy implication that could be drawn from profitability determinants is that subsidization to industrial fertilizers could be viable option by the ministry of agriculture to benefit rice farmers who irrigate using SRI principles and traditionally. This is based on substantial returnability that application of granular and liquid fertilizers has on TFIT and SRI profitability respectively. Therefore, by subsidizing more these industrial fertilizers, farmers' access to this important agricultural input would increase and eventually rise in profit level accrued by farming households.

ii. Ministry of finance and planning through it's Tanzania Agricultural Development Bank (with no branch in Ifakara) could reinforce its small holder farmers credit guarantee scheme (SCGS) with other convenient banks in the area like NMB Bank PLC to increase convenience of agriculture credit to rice farmers in Kilombero District since borrowing among rice producing household has shown significant contribution to profit level accrued

iii. Key policy implications drawn from the findings include government intervention through directing indicative rent for SRI plots is very important to induce the shift from TFIT to SRI irrigation.

iv. Also, the newly introduced technologies like SRI should be incorporated in agriculture related subjects or even topics taught in primary schools to make this young generation familiar of the technology earlier since it was found that increasing years in education was increasing with land allocated to SRI but on average most household heads just ended their education in primary level.

v. In addition to that, information on diversified sources of income should be provided to the farming households because through external income farming households can be in a good position to afford SRI that has been found relatively more costly than TFIT

vi. Also, study recommends than any promotion for the SRI should include financial support. This is because the technology needs high initial investment that entails costs to households. Helping them with financial supports will bust adoption in the sub-basin.

vii. Finally, from these findings and following the prevailing water flow decrease in the sub-basin due climate change, SRI is the best rice production practice. However, any promotion of this technology should take into account of the factors mentioned above. They indicate that households in the area are rational and they take into account so many factors before they decide.

4.3 Study Limitations and Areas for Further Studies

This study largely dealt with economics of traditional flooding and SRI irrigation technologies. The study did not go that further in comparing the two technologies using criteria like their impacts on livelihoods among farming household applied. There is therefore a room for other studies to be conducted in this area of subject matter and study setting. Essentially, studies of that kind are going to address questions like what is better between traditional flooding and SRI irrigation in making livelihood outcomes? Is profitability accrued by farming household in rice irrigation technology reflected in their lives?

APPENDICES

Appendix 1: Household questionnaire used for the study

Introductory note

Dear Sir/madam, I am Msc student at Sokoine University of agriculture, Morogoro. I am conducting this survey to evaluate economically the rice irrigation technologies at household level where Kilombero sub-basin is the case for such evaluation, all details pertaining to cropping season will base on 2020/2021 year. Your responses to these questions are highly valued to make this study successful. I tender my prior thanks for your cooperation

Date………………………….. Questionnaire No.______________

PART 1. HOUSEHOLD CHARACTERISTICS

1.Name of the village residing_____________

2.Ward residing______________________

3.Are you the head of household?___ Yes (1) or no (2)

4. What is your gender ___ Male(1) or Female(2)

5. What is your age?(in years)________

6. How many are you in the household?________

7. How many household members aging below 18 years?_____

8. How many household members aging at least 65?_______

9.How many household members aging between 18 and 64?___

10. What is the highest level of education you attained?_____

Key 1: 1.Primary, 2.Secondary, 3.Tertiary 4.None

11.Are you the native of this place(village)?__Yes (1) or no (2)

12. If no, what brought you in this place?____________________

13.For how long have you been residing in this village?______

14.What is your main occupation___

Key 2: 1.None; 2. Farming; 3.Carpentry ; 4.livestock keeping 5.Fishing; 6.Teacher; 7. other (specify)

15. Using key 2, mention other economic activities that you do______________

Household Farming practices

16. If farming, what is the main crop you cultivated in 2020/21 cropping season?_________

17. What are other crops that you cultivated in the season?_______

18. If rice, how did you grow the crop?_____ Rainfed (1) Irrigation (2)

19. If irrigation in 18 above, what kind of irrigation did your household use ?____ K:1)SRI 2)flooding 3)both

20. For how many years now have you been practice the irrigation type you mentioned?___

21. Why did you use irrigation type identified in 20 above?_______

Household Food consumption

22. Fill the information in the table below

s/n	Type of food	How much is required to feed household per month	How much is normally consumed per month	Unit	Market value
1	Cereals				
2	Roots/tubers				
3	Legumes				
4	Vegetable				
5	Fruits				
6	Milk				
7	Eggs				
8	Fish				
9	Meat				

23. What can you tell on food security for your household consumption in 2020/2021 cropping season?___________________

PART 2: ECONOMICS OF IRRIGATION TECHNOLOGIES

Establishment costs

23. What is the total land size (acres) used to grow rice in the season? _______________

24. How did you acquire the land K: 1. Purchase 2. Resettled by Gvt 3. Inherited 4. Community land 5. Renting 6.other (specify)__________________

25. What was the cost of acquiring land size used ? __________

26. Provide information on agriculture inputs used for rice farming in 2020/2021 season

Input type	Quantity used	Price/unit
1.Seeds		
2.Mineral fertilizers		
3.Organic fertilizers		
4.Pesticides		
5.other (specify)		
TOTAL		

27. What were the requirements of labour per activity hereunder?

Activity	No. family member	How many man-days spent by household members?	How many man-days spent by hired labourers?	What amount paid for the activity?
Clearing of farm field				
Ploughing				
Hallowing				
Sowing				
Weeding				
Managing fertility				
Insect& bird control				
Harvesting				
Post harvest activities				
TOTAL				

Harvests under the technology

28. Please provide details on the rice harvests in the table below

Total Land size used	Total yield realized

29. From your own observation, comment on the quality of rice harvested.______________

30.Before harvesting, did you loose any part of your rice yield due to weather extremes like flood or drought? __ Yes (1) No (2)

31.If yes in 30 above, then specify the quantity lost____________

32. Did you lose any part of your yield after harvest? ___Yes =1 No=2

33. If yes in 32 above, then specify the quantity lost___________
34. What quantity of rice did you retain for your own consumption? ________

Sales from the harvest

35.After harvesting, what did you do with the yield?___________
36.Tell the reason for choosing option identified in 55 above____
37.If selling, where did you sell your rice?________________
38. Provide more information on sales by filling the table hereunder

Buyer	Quantity Sold	Unit price
Total		

PART 2 C: Details on other external factors related

39. Please fill in the table below

Service	Available in your area? 1. Yes 2. No	Did you use it for the past 2 years? 1. Yes 2. No	How many times for the past 2 season?	How much incurred/credited	Reason for not using it (use key3)
Extension services					
Credit support					
Groups for membership					
Savings					
Mobile network service					
Other (specify)…					

Key 3: 1. I don’t require the service 2. Too expensive for your household to afford 3. The service is of substandard 4. Other (specify)……………………………………………………

40. After realizing rice harvests in 2020/2021 cropping season, did you proceed with the irrigation technology even in this 2021/2022 cropping season? ___Yes (1) No (2)
41. State reason(s) for your response in 40 above. ________

Appendix 2: Guide for Focus Group Discussion

1) Do people in this village largely engage on SRI or Convectional flooding for rice farming?
2) What are main reasons for choosing traditional irrigation technology?
3) What are the drivers for adopting SRI irrigation technology?
4) What were the limitations you faced in rice farming during 2020/2021 cropping season?
5) What do you think influence the choice of rice irrigation technology?
6) Did you ever try the other irrigation technology for rice farming?
7) In your opinion, what do you think contributed or reduced profitability of rice under irrigation technology you choose?

Appendix 3: Form of equations used to derive reduced household models

$$\frac{\partial \int}{\partial L_r} = \lambda_1 \frac{d R_i}{\partial Lr_i} - \lambda_3 = 0 \quad \text{(A3.1)}$$

$$\frac{\partial \int}{\partial Lo_i} = \lambda_2 Wo_i - \lambda_3 = 0 \quad \text{(A3.2)}$$

$$\frac{\partial \int}{\partial XM_i} = \frac{dU}{\partial XM_i} - \lambda_2 P_M = 0 \quad \text{(A3.3)}$$

$$\frac{\partial \int}{\partial R_i} = \frac{\partial U}{\partial XG_i} \frac{\partial XG_i}{\partial R_i} - \lambda_2 = 0 \quad \text{(A3.4)}$$

$$\frac{\partial \int}{\partial R_i^s} = \frac{\partial U}{\partial XG_i} \frac{\partial XG_i}{\partial R_i^s} + \lambda_2 P_G = 0 \quad \text{(A3.5)}$$

$$\frac{\partial \int}{\partial YG_i} = \lambda_1 \frac{d R_i}{\partial YG_i} - \lambda_2 P_Y = 0 \quad \text{(A3.6)}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_1} = R_i - R_i\left(Lr_i\, YG_i ; \delta\right) = 0 \qquad \text{(A3.7)}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_2} = ¿\; P_Y\, YG_i + P_M\, XM_i - P_G\, R_i^s - Lo_i\, Wo_i - E = 0 \qquad \text{(A3.8)}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_3} = Lr_i - Lo_i - L_i - Lp_i \qquad \text{(A3.9)}$$

Appendix 4: Pictures captured in data collection

A4.1. The Scheme's milling station in Mkula village

A4.2 Scheme's warehouse in Mkula village

Kuhusu Tasnifu Hii

Utafiti huu ulifanyika bonde la Kilombero, katika wilaya ya Kilombero inayopatikana nchini Tanzania, ili kubaini uchumi wa teknolojia za umwagiliaji wa mpunga na mambo yanayozingatiwa na kaya zinazofanya kilimo hicho katika kuchagua teknolojia za umwagiliaji kwenye kulima mpunga. Teknolojia hizo ni umwagiliaji shadidi unaoshauriwa kitaalamu na umwagiliaji wa kutuamisha maji kienyeji unaotumia maji mengi na usioshauriwa kitaalamu katika wakati huu ambao bonde tajwa likikabiliwa na athari za mabadiliko ya tabia ya nchi ikiwemo kupungua kwa maji. Utafiti ulilazimika kufanyika kutokana na uwepo wa asilimia 90 ya wakulima wa mpunga kwenye bonde hilo wanaotumia umwagiliaji wa kienyeji. Taarifa muhimu za utafiti zilikusanywa baada ya kumalizika kwa msimu wa kilimo wa mwaka 2021 kutoka kaya 100 zinazofanya kilimo. Aidha, taarifa kwaajili ya utafiti huu mfano zinazohusu sifa za uchumi jamii wa kaya, namna za uzalishaji, gharama, mavuno na mauzo ya mpunga pia hali ya utoshelevu wa chakula zilikusanywa kupitia mahojiano ya ana kwa ana na wakuu wa kaya hizo. Utafiti uligundua kwamba licha ya kuhitaji nguvu kazi zaidi, umwagiliaji shadidi wa mpunga una faida zaidi kuliko umwagiliaji wa kutuamisha maji kienyeji. Utafiti pia uligundua kwamba kaya zinazolima zinazingatia vitu vingine vingi mbali na faida kutoka katika kuchagua teknolojia ya kumwagilia mpunga, mfano ilionekana wazi kwamba gharama kubwa ya kukodisha shamba, mahitaji makubwa ya nguvu kazi pia kutokuwa na elimu vinasababisha kaya kuchagua kumwagilia mpunga kwa kutuamisha maji kienyeji, huku ukubwa wa kipato kitokacho nje ya shamba ilichangia kaya kuchagua umwagiliaji shadidi wa mpunga. Utafiti unapendekeza mikakati kadhaa katika kushawishi uchaguzi wa umwagiliaji shadidi wa mpunga ikiwemo kukuza shughuli za kuzalisha kipato nje ya shamba pia kuweka bei elekezi nafuu ya kukodisha mashamba.