



Profitability Analysis of Paddy Farming Systems in Wetland Areas, Kilombero, Tanzania: An Additional Layer to Curing Maladaptation

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Abstract

Agriculture contributes 28.9% of Gross Domestic Product; about USD 1 Billion to total export value and employs about 65% of Tanzanians. Identifying opportunities for enhancing profitability of the sector is paramount to informing choices of sustainable pathways. In the absence of such information, maladaptations are likely to be perpetuated. This paper investigated profitability of paddy farming both rainfed and irrigated systems using participatory rural appraisal approaches. It studied the mechanized and small-holder practices such as., the conventional transplant and flooding system (CTFS) and system of rice intensification (SRI). Findings demonstrated that; (a) although smallholder farmers use least inputs and technology, harvested an average of 1.33 Tons/Ha more than the mechanized irrigated system under Kilombero Plantations Limited. However, owing to better economies of scale and stable markets, the latter was more profitable (b) increased harvest due to irrigation in small-holder farms is less than 10% of their respective rainfed systems which suggests that rainfed system is more plausible in the case study (c) rainfed SRI harvests 73% more than rainfed CTFS. It is therefore recommended to promote rainfed SRI and grouping farmers at manageable scale to foster a better scale of economy, price negotiation basis and hence better profitability score.

Keywords: · Agriculture Profitability; Adaptation; Irrigation Economics; Paddy Economics; Water Management.

1. Introduction

1.1. Role of Agriculture

Across Africa, agriculture forms an important source of livelihoods in rural areas with a total share of income ranging from 59% to 78% (Madzivhandila and Niyimbanira, 2020). According to the National Bureau of Statistics (NBS) of Tanzania, the sector contributes around 28.9% to national GDP and employs about 65% of total population in the country which is currently close to 60 million people (NBS, 2020; Rudari et al., 2019). Although agriculture remains an important

driver of rural socioeconomic dynamics, significant changes have been noted. Wineman et al. (2020) reports that, the share of households that were rural fell from 74% to 66% between 2008 and 2014 with a similar decline in the percentage of households engaged in any agricultural activities (from 82% to 73%), and even a decline in the percentage of rural households engaged in agriculture (from 97% to 91%). According to them, the shift from agriculture-based activities suggests that non-farm opportunities are increasingly available. This drift is also picked in

individual-level occupational choices, with both men and women less likely to identify agriculture as their main occupation at 5% and 6%, respectively. In its place, people tended to cite self-employment or non-agricultural wage work. Consequently, the average household incomes are also increasingly leaning away from agriculture, with the average percentage of income derived from crop production falling from 36% to 29%, and the average percentage derived from livestock sliding from 11% to 8% (Wineman et al., 2020). As is the case in sub-Saharan Africa, agriculture engagement in the country is generally under subsistence economy in which farming, for instance, is typically practiced on 1 to 3 ha of land (Balogun, 2011; Davis et al., 2010; Kangalawe and Liwenga, 2005). This type of economy has been defined as the agricultural economic activities which is carried out through societally determined patterns of economic organization (Wharton, 2017). It is also known for limited use of modern technology, inputs and depletion/wasteful use of natural resources e.g., water and soil fertility (Etim et al., 2013; Kadigi et al., 2019; Vanlauwe et al., 2015).

1.2. Farming Profitability and Concepts

As pointed out, farming in sub-Saharan Africa uses resources inefficiently. This characteristic squandering of inputs and natural resources coupled with the typical size of land in subsistence farming, limits opportunities to optimize resources/inputs (Davis et al., 2010; Kangalawe and Liwenga, 2005) and hence records low profits or profitability hence calling for a better understanding of tradeoffs in these systems. These two criteria (profit and profitability) that form the anchor to this paper, are sometimes used loosely but they are fundamentally different phenomenon although closely related and mutually interdependent (Lusambo et al., 2021). They differ in that, profits denote excess in revenue after operational/investment expenses are accounted for and is expressed as an absolute gain from an investment (Ogbadu, 2009; Stierwald, 2010).

On the other hand, profitability, is defined as the measure to which an undertaking makes profit and is

expressed as a percentage/ratio of profit to revenue (Eriotis et al., 2002; Özçelik, 2015). It measures how efficient an investment is in using its inputs to produce profit (Nireesh and Thirunavukkarasu, 2014). The need to figure out profitability of farming system arises because of a close relationship between natural resources sustainability and profitability of farming systems (Darnhofer et al., 2010; Ikerd, 2013; Piedra-Muñoz et al., 2016). This relationship has also been established by other scholars such as the study of how environmentally sound farming undertakings increases demand and hence profitability for the produce (Brouwer, 2000). The analysis of interdependence between sustainability and profitability of urban vegetable gardens (Danso et al., 2002); the impact of environmental management on profit in semiarid grasslands of northern Austria (O'Reagain and Bushell, 2020); and the relationship between environmental performance of agrifood sector to profitability of the same (Piedra-Muñoz et al., 2016).

1.3. Background of Methods Used

To assess the profitability of paddy farming systems in Kilombero River Catchment (KRC), this study employed the two commonly used methods i.e., return on investment (ROI) and gross profit margins (GPM) or simply gross margins. While ROI tries to directly measure the amount of return on a particular investment, relative to the investment's cost (Botchkarev et al., 2011), GPM measures financial health of an investment by comparing size of profit made and revenue generated (Eriotis et al., 2011; Nariswari and Nugraha, 2020; Özçelik, 2015). To calculate ROI and GPM, the net profit of an investment is divided by its outlay and total revenue respectively (Botchkarev et al., 2011; Eriotis et al., 2011; Nariswari and Nugraha, 2020; Özçelik, 2015). Kilombero River Catchment was selected because of

These types of analysis are limited in natural resources management and more so in agrarian undertakings carried out by subsistence economy in sub-Saharan Africa. Where attempts have been sought, there is generally a laming of crops or farming as a

subsector (Musamba et al., 2011) which limits a better understanding of underpinnings in the different practices within the same crop. Furthermore, studies have only considered crop yields and water saving nature of undertaking, which does not consider other associated costs that may be hindering adoption. In this regard, the current study aims to investigate opportunities and challenges around profitability of farming systems focusing on paddy crop, but across the different farming practices and considering all associated inputs and outputs. The selection of paddy was guided by the fact that it is one of the most produced staple foods in the study area and Tanzania (FAO, 2021), a most rapidly growing cereal farming in Africa (Seck et al., 2010), and a high-water demanding crop amongst all the cereals. The latter has the potential for impairing water systems for other uses, including water for environment and ecosystem conservation. Unfortunately, thorough investigations of options

ensuring high gross margins to producers of this widely farmed crop, are limited (Rijsberman and Molden, 2001).

1.4. Typical Characteristics of Surveyed Systems

In bridging the knowledge gap, the profitability analysis considered the four small holder paddy farming system and two mechanized plantations operated by Kilombero Plantations Limited (KPL). While the latter deploys state of the art technology from modern pumping systems and overhead sprinklers to farming technology, harvest equipment and value addition. The former represents the subsistence agricultural economy of most farmers in Tanzania and sub-Saharan Africa. These are the rainfed and irrigated systems under conventional transplanting and flooding system (CTFS) and similar practice but under system of rice intensification (SRI). CTFS entails use of basic hand hoe, family labor, no or very

Table 1: A comparison between irrigated paddy farming under SRI and CTFS showing differences in resources use, spacing and age of seedlings (Sato et al., 2007; Upboff, 2008)

No.	SRI farming practice	No.	CTFS farming practice
1	Transplant young seedlings, 8 – 12 days old, and certainly less than 15 days old to preserve subsequent growth potential	1	Transplant older seedlings, 20-30 days old, or even 40 days old
2	Transplant seedlings singly, one per hill, and in a square pattern 25x25 cm, or wider if or when the soil is more fertile - Transplant quickly (15 – 30 minutes after removal from nursery), - Shallow (1-2 cm deep) and vertical planting	2	Transplant seedlings in clumps of plants and fairly densely, 50 – 150 plants per m ²
3	Keep paddy soil moist, but not continuously saturated, so that mostly aerobic soil conditions prevail	3	Maintain paddy soil continuously flooded, with standing water throughout the growth cycle
4	Control weeds with frequent weeding by a mechanical hand weeder (rotating hoe or cono weeder) that also aerates the soil	4	Use water to control weeds, supplemented by hand weeding or use herbicides
5	Apply as much organic matter to the soil as possible; can use chemical fertilizer, but best results from compost, mulch etc.,	5	Use chemical fertilizers to enhance soil nutrients

which can be adopted to achieve the dualistic aims of increasing water productivity, while at the same time

limited use of fertilizer or pesticides and irrigation is not through improved canals that attract water user fee

(Upboff, 2008). On the other hand, SRI is described as an agro-ecological methodology aimed at increasing the yield of rice produced in farming. It is a low water, labor-intensive method that uses younger seedlings singly spaced and typically hand weeded with special tools (Upboff, 2008). It promotes root systems and increases the abundance and diversity of soil organisms (Kahimba et al., 2013). Table 1 provides a further comparison between SRI and CTFS

In Kilombero catchment, in addition to dedicated extension service, training and some access to loan facilities during introduction of SRI, there are moderate modifications and departures from the above-referred SRI practices. Few alterations or additions that contribute to costs of farming include:

A considerable use of chemical fertilizers, especially areas away from rivers, wetland where slightly more cost on fertilizer was noted. In addition, farmers also apply chemicals to pests and initial weeding. This departure from typical non-inorganic SRI is also well captured in (Katambara et al., 2013) where lack of systematic policy guidance and learning materials is attributable here.

Manure is limited to leaving paddy stems, husks and other remains from harvesting and winnowing. This is linked to the lack of unified policy guidance and the fact that Kilombero valley is still very fertile with limited agricultural intensity due to under development of last mile infrastructures. It is also receiving fertile sediments from well protected areas such as Udizungwa and Mahenge.

Rainfed SRI in the study area (those closer to rivers/wetland) practice rising riverbanks or farm walls to block unwanted water from entering farm fields especially during peak of wet season. In addition, most rainfed SRI practitioners start considerably late in the season to avoid flooding brought about by peak rains. This practice utilizes only rainfall as means for moisture in the soil.

1.5. Rationale for Selection of Study Area

The Kilombero River Catchment, located within the Rufiji Basin in Tanzania, is one of the country's most ecologically and economically significant landscapes. Conducting studies on water resources management in this catchment is essential due to the growing pressure on water resources and the multiple competing demands for agriculture, domestic use, energy, industry, and conservation.

1.5.1. Support for Agriculture, Livelihoods and Biodiversity

The Kilombero Valley is one of Tanzania's largest agricultural zones, with extensive rice, maize, and sugarcane production that sustains both smallholder farmers and large-scale estates. Water resources management studies are crucial in ensuring sustainable irrigation, food security, and improved livelihoods (URT, 2025, 2002). The catchment hosts wetlands of international importance, designated under the Ramsar Convention. These wetlands provide habitats for migratory birds, fisheries, and wildlife, while also supporting ecosystem services such as water purification and flood regulation (Wilson et al., 2017). Studies help design strategies for balancing conservation and development.

KRC, whose most part is a flood plain, constitutes numerous rivers and the larger Kibasila wetland that drives the agrarian economy of these areas. It is central to southern agricultural growth corridor of Tanzania (SAGCOT) and forms one of its six clusters namely; Rufiji, Kilombero, Ihemi, Mbarali, Ludewa and Sumbawanga. It constitutes one of the most productive and ecologically important wetlands in Tanzania i.e., the Kibasila wetland. The Kilombero floodplain supports several large-scale investors who are already engaging smallholders in out-grower schemes for sugar, rice, and teak production.

1.5.2. Hydropower, Energy Security and Climate Change Adaptation

The Kilombero River contributes significantly to inflows into the Rufiji River, where major hydropower developments, including the Julius Nyerere Hydropower Project (Stiegler's Gorge), are located.

Bank, 2019). The catchment is highly vulnerable to rainfall variability, floods, and prolonged droughts. Studies on water resources management provide critical insights for developing adaptive strategies to enhance resilience against climate risks (URT, 2021).

1.5.3. Water Sustainability

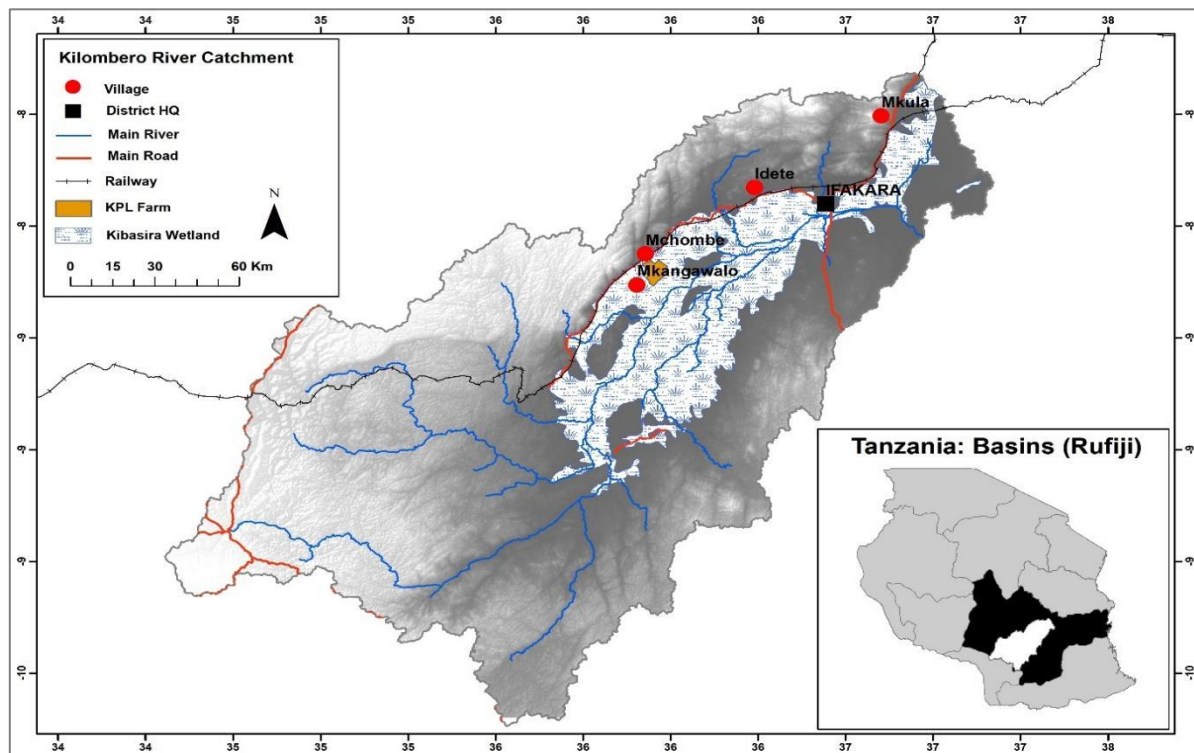


Figure 1: Map of Kilombero River Catchment showing the surveyed villages/wards in relation to wetlands and river resources.

Effective water resources management ensures sufficient water supply for energy generation without undermining upstream or downstream uses (World

The Kilombero floodplain which is center for most economic activities in the study area is becoming progressively more degraded in recent years due to an

Table 2: Attributes of the Kilombero river catchment indicating significance of the different catchments (WREM & RBWB, 2013a)

No	Sub Basins	Catchment Area	% of Drainage Area	% of Annual Runoff
1	Great Ruaha	85,554	47	15
2	Kilombero	40,430	23	62
3	Luwegu	26,300	15	18
4	Rufiji	27,160	15	5
5	Total	183,791	100	100

influx of crop producers and grazers (Kangalawe and Liwenga, 2005). As is the case across Tanzania and sub-Saharan Africa, there is little enforcement capacity to address these conflicts, to the detriment of wildlife, fisheries, and human livelihoods. In a similar vein, the expansion of smallholder agriculture (and to a lesser extent commercial farming) has interfered with several key wildlife corridors that once connected the Udzungwa Mountains to the Kilombero floodplain and Selous Game Reserve (Mtega, 2017). Over time, such changes are expected to increase levels of human – wildlife conflict while reducing game populations in the Selous and Udzungwa protected areas. The Kilombero Valley has good soils suited to a variety of agricultural uses. This is attributed to reasons for majority of the population (85% to 90% in some districts), engaging in agriculture. Other livelihood activities are small-scale businesses and elementary occupations, but all are based directly or indirectly on exploitation of natural resources (Kangalawe and Liwenga, 2005; Mtega, 2017).

There is considerable inequality in the catchment communities, with large disparities in household assets, domestic services, household income, and household expenditure (WREM & RBWB, 2013a). About one third of the population in rural areas and one fifth of the population in urban areas fall below the basic needs poverty line; that is, they have an income below TZS 36,500 per month per adult (WREM & RBWB, 2013a). Kangalawe and Liwenga (2005) identified wealth categories based on size of farm owned by communities in and outside the wetland. They categorized ownership of up to 2.1 ha, 2.8 ha and above 5.5 ha of farm in wetland to be poor, medium, and wealthy farmers respectively. In addition, categories of farms outside the wetland included farm sizes of about 0.2 ha, 0.6 ha and above 0.7 ha as poor, medium and wealthy farmers respectively.

In view of the above, this study was designed in reflection to the following three questions:

a) Are the crop yields and gross margins across the paddy farming practices significant enough to

justify the promotion of and investment in irrigation infrastructure in these wetland areas or should rainfed be promoted and hence save water for in-situ and downstream needs (i.e., water demand for development projects as well as environmental and ecosystem conservation)? Recognizing that Kilombero River contributes slightly above 60% of the total flow into these systems (Dye and Hartmann, 2017; WREM & RBWB, 2013a).

b) Are there substantial differences in harvests and gross margins across the paddy farming practices to warrant promotion of a particular practice over the other to concurrently improve community livelihoods and water resource management in KRC and Rufiji basin at large?

c) What are the policy recommendations in support of improvements in gross margins for small-holder farmers?

2. Materials and Methods

2.1. Description of the Study Area

The Water Resources Engineering and Management (WREM) Inc. of United States of America and the Rufiji Basin Water Board (RBWB) have delineated the study catchment as they were developing the Integrated Water Resources Management and Development (IWRMD) Plans. This showed that the study area i.e., the Kilombero River Catchment (KRC) extends between Longitudes 34°00'E – 37°20'E and Latitudes 07°40'S – 10°00'S and covers an area of approximately 40,000 km² (WREM & RBWB, 2013b) (Figure 1). It constitutes an important part of the Tanzania's largest hydrologic basin such as, the Rufiji River Basin (RRB) which spreads across 177,420 km² - about 20% of Tanzania and forms part of the leading food basket in Tanzania (Mkonda and He, 2016). KRC is the most important catchment in respect of river flow to RRB (Table 2), agricultural and energy production as well of conservation of natural resources.

$$\text{Sample size} = \frac{Z_{1-\alpha/2}^2 P(1-P)}{d^2}$$

2.2. Sampling Procedure and Sample Size

The survey was carried out in five villages that were selected purposefully with the help of Agricultural Officer at Ifakara District Council. This was to ensure that selected villages (Table 3 and Figure 2) had communities who practice all the four smallholder paddy farming practices, hence capturing the needed agronomic information and had better spatial

Where:

$Z_{1-\alpha/2}$ = Is standard normal variate (at 5% type 1 error ($P < 0.01$) it is 2.58). As in majority of studies P values a 1.96 is used in formular.

P = Expected proportion in population based on previous farming households is 80% in rural areas (NBS, 2013)

d = Absolute error or precision – decided by researcher.

Table 3: Demographic data on sampled village and details of sample size

N	Village Name	Ward	Selected Village Demography				Sampled population		
			M	F	Total	HH	M	F	Total
1	Mkangawalo	Mngeta	1,655	1,796	3,451	633	63	28	91
2	Itongowa	Mngeta	1,219	1,475	2,694	321	35	11	46
3	Kidete	Mngeta	820	744	1,564	253	26	10	36
4	Njage	Mchombe	624	723	1,347	298	31	11	42
5	Mkula	Mkula	683	785	1,468	230	19	16	35
Total			5,001	5,523	10,524	1,735	174	76	250

* Only heads of households were interviewed meaning that we considered 14% of all households. A simple ratio of interviewed households (250) to a total number of households in the five villages (1,735)

Table 4: Number of interviewees in each of the smallholder farming practices

N	Farming Practice	% share	Interviewees
1	CTFS Rainfed	48%	120
2	CTFS Irrigated	29%	73
3	SRI Rainfed	14%	35
4	SRI Irrigated	9%	23
5	Total	100%	250

*% share was calculated from the proportionate share that the farming practice commands in the study area.

coverage of the study area. Number of households surveyed for each paddy farming practice in respective villages was predetermined to have a fair mix in conformity with the percentage split of these practices obtained at key informant interviews (KII). This was done in close consultation with village and farmer's group leaders who had a better understanding of the population studied.

Respondents in the respective farming system were then randomly selected to limit biasness. A total of 250 households were interviewed in the sampled villages (Table 3 and Table 4) following Charan and Biswas (2013) sample size recommendation (eqn.1). Furthermore, in each village, a focused group

discussion (FGD) was also carried out constituting groups meant for farmers in irrigated CTFS, irrigated SRI, rainfed CTFS and rainfed SRI. In addition to that, a total of eighteen (18) respondents were interviewed during KII that documented responses from leaders and/or technical staff from seven key institutions with influence on agriculture in the study area (Table 5). In all the conducted interviews, consent form was signed, and respondents were provided contact details of the dean of school at Nelson Mandela African Institution of Science and Technology should they have any complaint on how process was carried out and/or preliminary findings that were provided at validation meetings.

2.3. Selection of Farms

In nature farmers randomly practice different farming systems in a locality in which case there are also patches of the same in considerable parts of the study area. However, in these waterlogged wetland areas, that also receive fairly good rains, the SRI farmers either opt to practice away from the wetlands (especially irrigated SRI) or those closer to the wetland/rivers, start later in the season (mostly rainfed

then informed this paper. The values were then averaged for the entire study area since selection of villages also stretched to have a better representation of paddy farming areas of the catchment. It should also be noted that, even within these isolated farm practices, there are slight differences that offer some different results that in this case we captured the differences in the descriptive statistics showing the spread.

2.4. Data Collection and Analysis

Table 5: List of key informant respondents and type of data collected

S/N	KII Respondent	Respondents	Department/Section	Data collected
1	Administrative councils of Ifakara, Ulanga, Malinyi, and Mlimba	4	Agric & Irrigation	Harvests, Prices, types of farming practices
2	Rufiji Basin Water Board (Ifakara Sub Office)	1	Head of Office	Water uses, water permits
3	Kilombero Agricultural Training and Research Institute	1	Crop Science	Soil, Moisture levels and farming practices
4	KPL plantations Ltd	2	Production and Irrigation	Water use, inputs and yield,
5	Water Users Association	2	Leaders	Water allocation, water fee
6	Irrigation Schemes	4	Leaders	Water allocation, types of farming practices
7	Village Government	5	VEO	Water allocation, Demography
8	Ward Government	2	WEO	Demography, types of farming
9	Total	21		

SRI). The latter tend to block unwanted water by rising farm walls or riverbanks to allow for some alternative wetting and drying of blocks. Based on this, there is an old established informal arrangement separating SRI and CTFS where it is seldom to find SRI mixed with CTFS to avoid conflicts over water uses with the latter demanding more water towards fields while the former would not. This way, it was easier to pick farms with specific practice and enable a more specific discussions on agronomic aspects of their practice that

This study employed a set of approaches from the participatory rural appraisal (PRA) discussed in Chambers (1994); Riswan (2020). This entailed: transect walk (TW), key informant interview (KII), house-hold survey (HHS) and focused group discussions (FGD). With exception to the HHS, which were conducted as semi-structured interview and TW which entailed physical observation, photographs and documentation, the rest were open ended interviews.

We adopted semi-structured questionnaires as data

$$\text{Gross Profit Margin} = \frac{\text{Revenue} - \text{Costs}}{\text{Revenue}} \times 100\% \quad 2$$

$$\text{Return on Investment} = \frac{\text{Revenue} - \text{Costs}}{\text{Costs}} \times 100\% \quad 3$$

collection tool for HHS and interview guide for KII and FGD. Probing for KIIs and FGDs were open-ended to allow respondents to provide as much information as they possibly could and enable us to ask follow-up questions. Field observation and interviews with different actors was important for triangulation of information whereby the same issue was probed and discussed through with diverse respondents. Responses were captured in questionnaire forms and additional explanations; key quotes and general understanding of the responses were transcribed.

A range of qualitative and quantitative information Tanzania, dynamics around utilization and access to

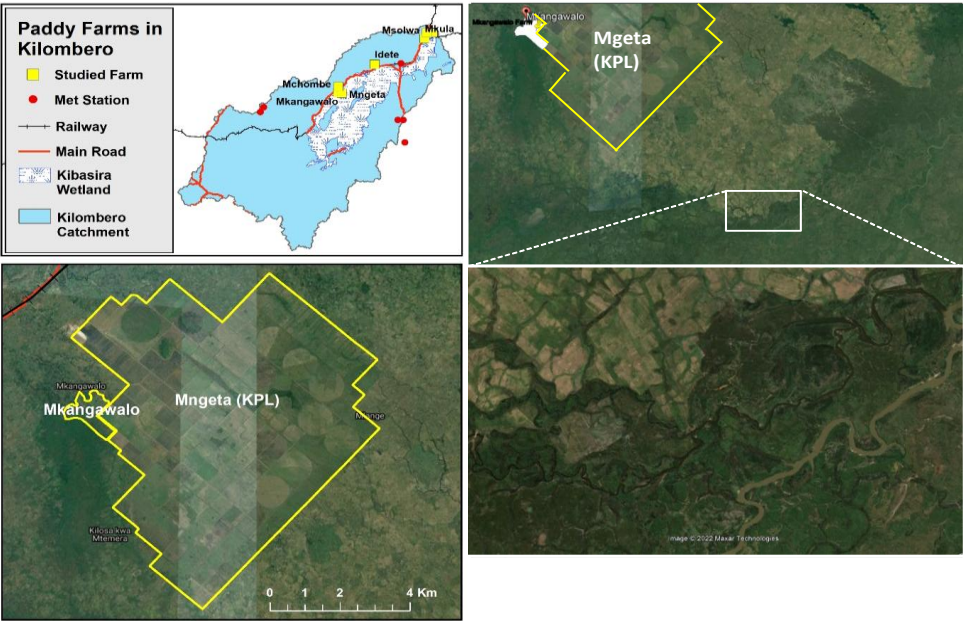


Figure 2: The spatial illustration of some of the sampled farms including illustration of small-holder farming around riverbanks/protected areas

pertaining to access to land, water, paddy farming practices, farming economics, access to storage and markets infrastructures were collected. In addition to that, a focused review of relevant literature was carried out to augment the collected data and information. This included issues around land ownership and tenure in

wetland resources, comparative impact on yield due to irrigation in rainfed and irrigated lower land paddy farming in Tanzania, and the social economic profile based on the unpublished Ifakara district social economic profiles. These together with the collected data, helped to inform our analysis, results and

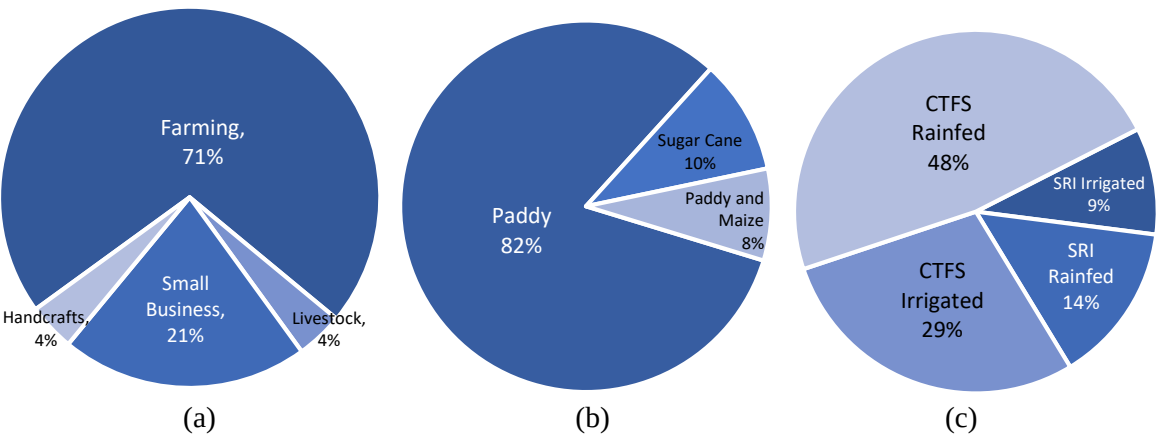


Figure 3: The percentage of (a) livelihood activities (b) types of crops farmed and (c) paddy farming practices in KRC showing the dominance of farming and paddy crop in particular.

conclusions especially on the analysis of profitability and value that irrigation brings in the wetland areas which is characteristic of our study area. As stated, the former is based on gross profit margin (GPM) and return on investment (ROI) of all the farming systems.

These were calculated as a ratio of profit to accrued income and to farming outlay (eqn. 2 and eqn. 3) as discussed in (Eriotis et al., 2011, 2002; Nariswari and Nugraha, 2020; Özçelik, 2015). The data were obtained from questionnaire analysis where minimum, maximum and average value were established together with other statistical descriptions. Some questionnaires

graphs that enabled comparison and contrasting of researched aspects.

3. Study Results

3.1. Selected Socioeconomic Characteristics

The survey has shown that farming dominates livelihood activities in the study area (at 71%) followed by Small-Scale Businesses (21%), Livestock Keeping (4%) and Handcrafts especially weaving and mechanics (4%). It has further been noted that farming is predominantly Paddy (82%), Sugarcane (10%) and Mixed Paddy and Maize (8%) (Figure 3). Other crops

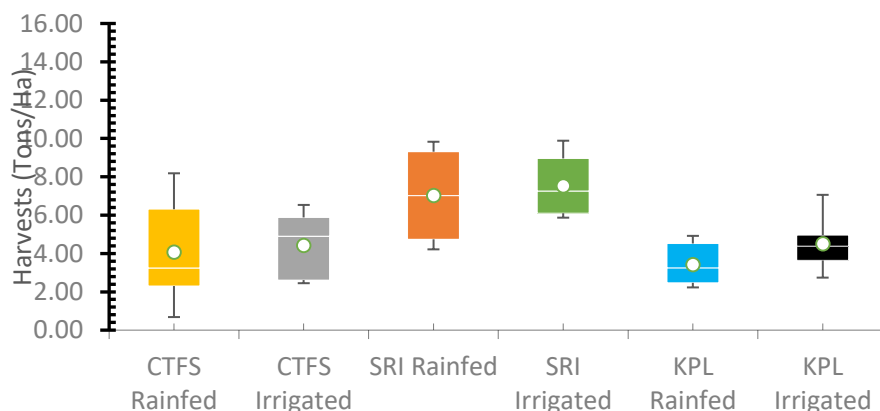


Figure 4: Paddy yields across farming practices in Kilombero river catchment showing a better performance of SRI practice

(less than 5%) had missing responses in some of questions and in this case, they were omitted in the data processing. This represented about 13 of 250 questionnaires in which only missing responses were not considered in the analysis, hence did not introduce intolerable bias. Responses were also coded to capture similar meaning in same category of interpretation as discussed in Dolmaz, (2019). This coding involves organizing and classifying responses by assigning numbers or labels to similar answers so that variations in wording with the same meaning are grouped under one category. This process ensures consistency, simplifies interpretation, and supports systematic data analysis (Dolmaz, 2019). Analysis of data were performed in Microsoft Excell interface and results were then presented in form of tables, pie charts and

were deemed insignificant both in terms of water use and size of farms (e.g., bananas and vegetables). Furthermore, as the focus of the current study, it has identified four major paddy farming practices under small holder schemes which are: rainfed conventional transplant and flooding system - CTFS (48%); irrigated CTFS (29%); rainfed system of rice intensification - SRI (14%) and irrigated SRI (9%) (Figure 3). The split in livelihood activities in the study area agree well with studies by other scholars who also identified agriculture to be the dominant form of livelihood. It is followed by small-scale businesses and elementary occupations, but all are based directly or indirectly on exploitation of natural resources (Kangalawe and Liwenga, 2005; Mtega, 2017). The same is in line with response from Ifakara District Council (Agriculture

and Livestock Department) who indicated similar split of farming systems:

in areas that not only are naturally fertile and moist (by dint of their status as protected area) but also some

Table 6: Descriptive statistics for paddy yields in the six paddy farming systems showing a better SRI performance

N	Farming Systems	Avg. Farm size (ha)	MIN	Q1	Mean	Median (Q2)	Q3	MAX	STDEV
1	CTFS Rainfed	1.58	0.68	2.30	4.06	3.24	6.31	8.18	2.39
2	CTFS Irrigated	0.65	2.45	2.61	4.41	4.90	5.88	6.53	1.63
3	SRI Rainfed	1.22	4.21	4.74	7.02	7.02	9.31	9.83	2.34
4	SRI Irrigated	0.73	5.87	6.10	7.52	7.26	8.96	9.88	1.55
5	KPL Rainfed	2003.7	2.23	2.47	3.41	3.25	4.52	4.92	1.12
6	KPL Irrigated	1404.3	2.74	3.64	4.50	4.38	4.96	7.06	1.33

* Q = Quartile

3.2. Profitability Across Farming Practices

3.2.1. Mean Farm Yields

As pointed out in section 3.1 above, the farming practices under consideration included CTFS, SRI, and the KPL paddy farming practices. These farming systems differ in the agronomic inputs and thereby the resultant yields per hectare (Figure 4 and Table 6). From this illustration and summary, it is shown that small holder farmers (even CTFS) harvest similar or slightly better than mechanized farms. This is

conduct farming at tail end to bigger schemes hence receive all the drained nutrients. Furthermore, a comparison of yields (Tons/Ha) across same farming system but between rainfed and those with access to irrigation augmentation shows that, generally irrigation has little impact on yields per ha (Figure 4 and Table 6). For instance, increased average yield due to irrigation is only in the tune of 0.35 Tons/Ha (9% of average yield in rainfed) and 0.49 Tons/Ha (7% of average yield in rainfed) between CTFS and SRI respectively. Comparison with Tanzania average

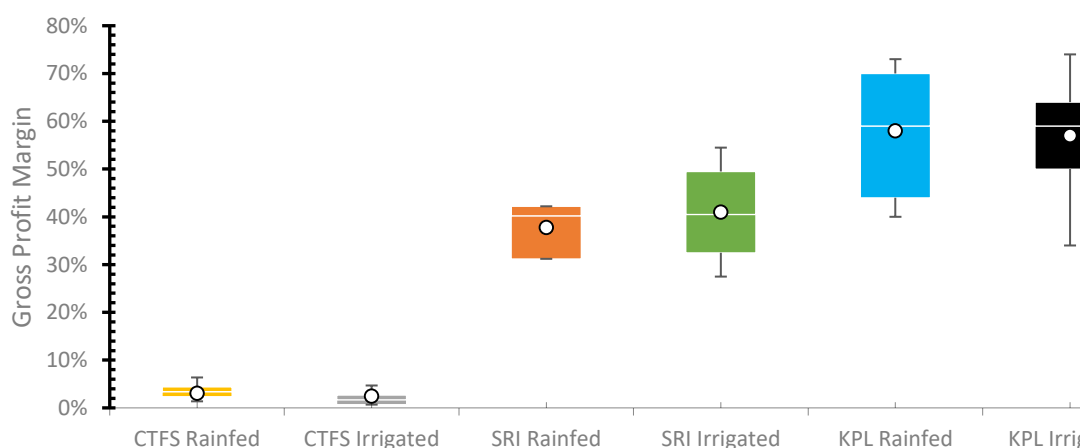


Figure 5: Comparison of gross profit margin for all the paddy farming system indicating better performance of KPL owing to better economies of scale

attributable to the fact that smallholder farmers engage shows that, yield in lowland rice farming (similar to

Table 8: Descriptive statistics for gross profit margin for all paddy farming systems indicating better performance of KPL owing to better economies of scale

N	Farming Systems	Avrg. Farm size (ha)	Min	Q1	Median (Q2)	Q3	Max	Mean	SD
1	CTFS Rainfed	1.58	1%	2%	3%	4%	6%	3%	2%
2	CTFS Irrigated	0.65	1%	1%	2%	3%	5%	2%	1%
3	SRI Rainfed	1.22	31%	31%	40%	42%	42%	38%	5%
4	SRI Irrigated	0.73	27%	33%	41%	50%	55%	41%	10%
5	KPL Rainfed	2003.7	40%	44%	59%	70%	73%	58%	13%
6	KPL Irrigated	1404.3	34%	50%	59%	64%	74%	57%	12%

“Most smallholder out growers lose most of the rice due to poor pre preparation and milling machines. On average they make 1 Ton of rice from 1.5 Tons or more while our average rate is 1.23 Tons of paddy for 1 ton of rice which is one of the best in Tanzania”.

study area) is between 1 – 3 Tons/Ha and 3 – 6 Tons/Ha considering those depending on rainfed and those with access to irrigation augmentation respectively (Wilson and Lewis, 2015). This indicates that irrigation applications yield twice as much yield compared to rainfed systems at national average. The little impact of irrigation on yield in KRC could be partly attributed to the fact that most farms are fairly in good proximity to water/moisture i.e., the Kibasila wetland or the numerous perennial rivers with relatively good flows throughout the farming season. This collaborated well with 68 years old farmer and leader of a water users

“I have farmed in these areas since childhood. Even in the driest of years, we still have better yields and no conflicts over water as compared to what we have heard in Usangu during our WUA exchange visit in 2012”

Since irrigation had little impact, a further analysis of yields per ha was also carried out to compare superiority across rainfed CTFS, SRI and KPL systems. With reference to Table 6, this indicated that, SRI yielded 2.97 Tons/Ha and a whopping 3.61 Tons/Ha more compared to the CTFS and KPL which

Table 7: Descriptive statistics for return on investment for all paddy farming systems indicating better performance of KPL owing to better economies of scale

N	Farming Systems	Avrg. Farm size (ha)	Min	Q1	Median (Q2)	Q3	Max	Mean	SD
1	CTFS Rainfed	1.58	1%	2%	3%	5%	6%	3%	2%
2	CTFS Irrigated	0.65	1%	1%	2%	3%	5%	3%	1%
3	SRI Rainfed	1.22	45%	46%	67%	71%	73%	62%	13%
4	SRI Irrigated	0.73	38%	48%	69%	101%	121%	74%	30%
5	KPL Rainfed	2003.7	67%	84%	142%	238%	268%	155%	83%
6	KPL Irrigated	1404.3	52%	101%	142%	175%	291%	149%	74%

association (WUA) who indicated good yields even in times of dry years which may signify the role of wetlands in water/moisture storage.

is equivalent to about 73% and 106% of yields of CTFS and KPL respectively. A general comparison of KRC farmer's average yields in Table 6 with the rest of Tanzania shows that, KRC yields are almost twice as much as Tanzania average for CTFS and SRI farming

practices. These are rainfed traditional system (1 - 1.8 Tons/Ha) which was considered in our case to be equivalent to rainfed CTFS; Traditionally irrigated (1 – 2 Tons/Ha) equivalent to irrigated CTFS and improved traditional (4 Tons/Ha) equivalent to SRI (Wilson and Lewis, 2015). Mechanized farming in KRC also yields generally better than the Tanzania average for similar farming. The superiority of KRC harvests is attributed to the fact that the catchment receives good rainfalls, is underdeveloped due to poor accessibility infrastructure hence still fertile and that Tanzania average are considered at national scale that considered all ecoregions and climatic zones.

3.2.2. Gross Profit Margins and Return on Investment

The results for gross profit margin (GPM) is presented in Table 7 and Figure 5 whereas the return on investment (ROI) is presented in Table 8 and Figure 6. These were calculated after consideration of the income from selling paddy and all the associated costs (Table 9) across the farming systems. These amounts were obtained from questionnaire analysis where minimum, maximum and average value were established. All the presented values are in US\$ based on 1 ha of farming and are converted at an annual average rate of TZS 2297.39 for 1 US\$ as per Bank of Tanzania (BoT) rates as of 5th January 2021 (www.bot.go.tz). The calculated average values were taken as the working value as indicated in tables

referenced in this section. Since KPL does not sell raw paddy, the presented numbers have been calculated retrospectively using a ratio of 1.23 Ton of paddy for 1 Ton of rice as per KPL production department.

With reference to Table 9 the average operational costs of small holder farmers (both CTFS and SRI) are significantly higher compared to mechanized KPL plantations. Coupled with average market prices between the small holder (263 US\$/Ton) and KPL (277 US\$/Ton), the GPM and ROI are much better for the mechanized farming followed by SRI (Figure 5 and Figure 6). The agricultural department in Ifakara District Council indicated that smaller farms per individual and poor access to markets affect accrued profits for small holder farmers.

“Smallholder farmers in Kilombero valley yield better than many parts of Tanzania. However, profits are slim due to poor farming practices to reduce unwanted costs, little farms hindering resources optimization and poor road networks that affects access to markets”

4. Discussion

Kilombero paddy farms depicts one of the systems with huge potential to improve catchment ecological functions and profitability of their produce. The results discussed below are as specific as possible for a specific paddy farming practice. This is borne out of the fact that there were deliberate efforts by authors to pick specific practice during data collection. This was

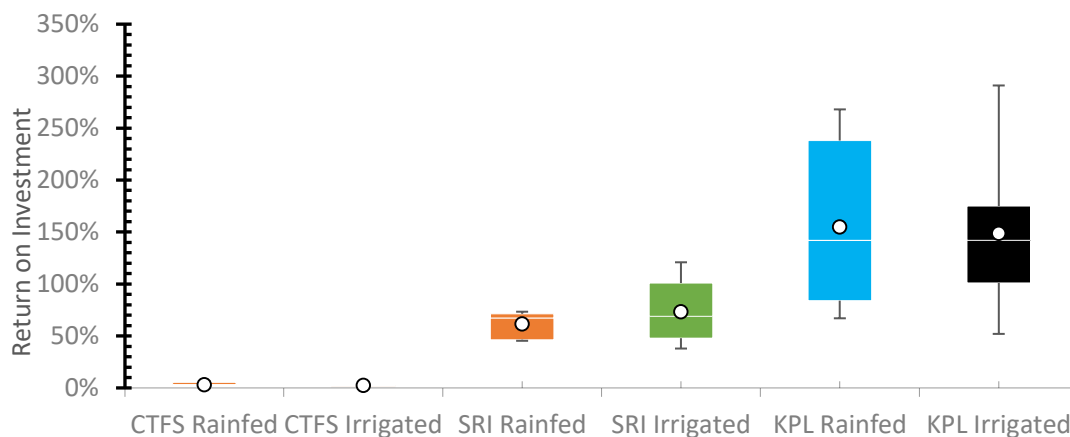


Figure 6: Comparison of return on investment across the paddy farming system indicating better performance of KPL owing to better economies of scale

made possible due to the long-established quest for farmers, especially SRI to have a mechanism to foster some wetting and drying mechanisms as discussed in section 2.3 above.

4.1.1. Farm Yields

As demonstrated, yields, for smallholder farms, performs similar to or better than mechanized KPL farms in the case of CTFS and SRI respectively. This was attributed to the fact that some of them access (though illegally) places such as protected river and wetland buffer zones which normally have better moisture and soil fertility. In addition, a sizeable proportion do also practice their farming at tail end of all well-established irrigation schemes or mechanized farms where they then capture the nutrients in the draining waters. Reference can be made to Figure 2 whose information is also well captured by other scholars such as (Materu and Heise, 2019; Siima et al., 2012). This adds to the fertility that are naturally the case in river buffer and wetland areas. Since effective enforcement will automatically remove them from these productive places, their average yields will then be lowered. Betterment of practice is the only meaningful and practical option in these CTFS segments. This could be good selection of seeds, proper application of manure or adopting to part of or fully fledged SRI and better groupings that will assure markets and resources optimization per unit area.

For smallholder farmers, practicing rainfed systems, especially SRI, has been seen to be more plausible undertaking since mechanization (e.g., KPL) is farfetched. Further to the demonstrated better harvests, farmers who practice rainfed SRI are involved in rising of riverbanks and/or farm walls to prevent water from entering the field. This maximizes the drying part of the practice for better aerobic activities. In addition, most of them opt to farm farther from river and wetland buffer zones. This practice not only guarantees a better yield (second only to its corresponding irrigated SRI by a small margin of 0.5 Tons/Ha) but also enhances ecosystem integrity. Furthermore, it ensures better downstream flow and hence uses especially in the situation where Kilombero river contributes about 60% of total Rufiji River flow to Indian ocean (Dye and Hartmann, 2017; Kahimba et al., 2013; WREM & RBWB, 2013a). Notwithstanding needs for improvements at Kilombero level, there are needs to engage at basin and national level through the established multi stakeholder platforms (Sigalla et al., 2021) where lessons can be shared and cross fertilized.

4.1.2. Profitability of Farming Systems

As indicated above, small-holder farmers (as opposed to KPL) deploy inferior technology and operate on smaller farm units which limits resources optimization. These aspects attract higher operational costs per Ha of farming compared to their mechanized farming counterparts. The aftermath of these are the

Table 9: Calculated average operational costs and annual revenue for all six farming systems indicating KPL had better markets and least costs per Ha due to better resources optimization.

N	Farming System	Avg. Farm Size (ha)	Operational Costs (USD/Ha)			Revenue (USD/Ha)		
			Min	Max	Avg	Min	Max	Avg
1	Rainfed CTFS	1.58	178.22	2100.20	1043.53	180.70	2168.39	1075.16
2	Irrigated CTFS	0.65	633.01	1688.67	1133.20	646.70	1724.53	1164.06
3	Rainfed SRI	1.22	708.30	2348.62	1268.83	1032.57	3872.13	2079.48
4	Irrigated SRI	0.73	1178.0	1298.70	1248.92	1700.29	2863.65	2177.57
5	KPL Rainfed	2003.7	341.50	341.50	341.50	685.45	1511.13	1047.42
6	KPL Irrigated	1404.3	500.40	500.40	500.40	912.81	2352.62	1499.84

*These costs are based on appendix i showing how different inputs vary in rainfed and irrigated systems which connote role of water usage.

low profits, GPM and ROI as demonstrated in the previous section. While improvements in accessibility infrastructure to steer markets is well captured in government plans for southern agricultural growth corridor (SAGCOT) (de Cleene, 2014), at farm level, better grounds for resources optimization is limited with smaller farms which is typical practice of small holder farmers in the study areas (Davis et al., 2010; Kangalawe and Liwenga, 2005). The situation is even worse for CTFS where good agriculture practices are more limited. This may explain the persistent poor life conditions for this population segment. Piggybacking on already existing livelihood grouping systems such as merry-go-rounds and savings and credit co-operative societies (SACCOS) is critical to group farmers in manageable sizes to optimize inputs (Chiteva et al., 2016; Maleko et al., 2013). Value addition to rice associated with branding and packaging is deemed an important strategy for lifting profitability of small holder farmers who already harvests better in terms of tonnage not withstanding associated operational costs. The same harvests in KRC have been shown to be better than the rest of Tanzania as indicated in (Wilson and Lewis, 2015). Needless to say, considering mechanization and other investments in KPL farms, it's impossible to imagine that small-holder led system can rise to scale of KPL as eluded in SAGCOT nucleus proposition that suggest for these out growers to learn and adopt practices in KPL (Brüntrup et al., 2018).

4.1.3. Value of Irrigation Augmentation

On value of irrigation in respect of additional yields, it has been shown that, across the six-farming system, irrigation generally adds insignificant fraction. We also studied the same in a parallel research paper (Sigalla et al., 2022) and learned the same minimal impact by irrigation augmentation. This is attributed to good rains received in these areas (Koutsouris et al., 2016; Näschen et al., 2018), proximity of most farms to Kibasila wetland and numerous perennial rivers moisturizing most farms. (Dye and Hartmann, 2017; WREM & RBWB, 2013a). Rufiji Basin Water Board

(RBWB) who are bestowed with water allocation statutory mandates collaborated the availability of water for current agriculture needs based on water use conflict registry indicating Kilombero to be the calmest in comparison to other similar river catchments.

“Rains in Kilombero support all agriculture needs as of now. There are no or little conflicts over water as compared to other river catchments e.g., Great Ruaha with similar food-energy-water nexus. This is because everyone harvests fairly well as far as water is concerned. We are cautious though of new plans and on irrigation that could affect other downstream water needs”.

5. Conclusions and Recommendations

This study has shown that smallholder farmers have better yields but accrue huge operation costs per ha of farming compared to mechanized KPL farms. It is imperative to organize them in appropriate groupings that will help to optimize resources, operational costs per ha of farming and build a solid ground for market and price negotiations. Farther to that, it has been demonstrated that water augmentation by irrigation brought very little impact to paddy yield for all farming systems. Where as in the rest of Tanzania irrigation doubles yields (Wilson and Lewis, 2015), in the study area it only added less than 10% of yield in similar rainfed system. This is attributable to the good climate of Kilombero valley (Koutsouris et al., 2016; Näschen et al., 2018; Wilson et al., 2017) where most farms are also in proximity to the vast Kibasila wetland and perennial rivers (Leemhuis et al., 2016; WREM & RBWB, 2013b) most of which carries fertile soils originates from Udizungwa Mount Ranges which enjoys a national park protection status. In this regard, rainfed is the recommended farming system that guarantees dualistic benefits on yield and profitability which have been seen to be only slightly less than irrigated system. In addition, rainfed system (especially SRI) also guarantees better water saving at farm level and collective downstream water flows that can propel other sectors of economy and the ecosystem integrity. However, it should be noted that, water

saving at farm level, in itself, will not necessarily translate to better flows downstream. Unless it is coupled with stronger institutions and effective law enforcement, uncontrolled expansion due to available (served) water will be the case.

This research has also shown a very slim profit (and hence low GPM and ROI) on the part of small-holder farmers (CTFS and SRI). We conclude that, although harvests per ha in small holder farmers are generally better than mechanized plantation, the huge operational costs per ha of farming limits profit. These costs are due to limited farm sizes per individual, hence little opportunities to optimize resources and input. Farmers in the study area belong to a poor segment operating in smaller farms which range between 0.69 and 1.48 ha for CTFS and between 0.73 and 1.15 ha for SRI. The same farm sizes has also been observed by other scholars such as (Davis et al., 2010; Kangalawe and Liwenga, 2005) who noted an average farm size of 1 to 3 ha to be typical characteristic of these small holder farm across Tanzania (considering all crops). In the absence of grouped farming practice, current scale of economy attracts high operational costs and hence less GPM and ROI in these small-holder farming systems as has been evident in this study. The well-established SACCOS or merry-go-round schemes in these areas, only involves themselves in the tail end of farmers preoccupation i.e., saving and loans (Chiteva et al., 2016; Maleko et al., 2013). These entities would have been ideal to group farmers in manageable groups to lower operational costs e.g., group hiring of equipment, labor and other requirements or even secure good markets and negotiation power. In addition to that, SRI practice in the study area has been seen to incur a considerable cost for chemical fertilizers which depart slightly to widely organic practice in SRI. This could be partly due to low access to information and short-lived demonstrations that also concentrated only around/near KPL who brought the technology. This did not help to disseminate proper knowledge to spar behavior change and instill proper practices. It is

henceforth recommended to design and institute policies that:

- (a) Build capacity and promote rainfed SRI system for smallholder farmers in these areas to ensure better yields and profitability of paddy farming and better ecosystem integrity due to low water usage in SRI and especially rainfed one. Similarly, curbing the use of chemical fertilizers would help reduce pollution of the water served and then released for downstream uses.
- (b) Aim to reduce operational cost per ha of farming through farmer groupings that will optimize resources use per ha of farming and as basis for securing markets and negotiation power.
- (c) Promote and facilitate farmers to engage at basin and national level to learn from peers and contribute to knowledge pool.
- (d) A further study to substantiate optimum size of farms within which farmers will be grouped is also recommended. The same should consider social dynamics favorable in this kind of grouping, some of which are already embedded in the aforementioned structures around SACCOS or merry-go-rounds.
- (e) A study on influence of confounders e.g., soil fertility in different localities (close to rivers/wetlands and farms further to these natural infrastructures) is also recommended to improve results from similar studies anywhere.
- (f) This study has also studies paddy farming piggybacking on the organically established segregation of SRI vs CTFS due to differences in water needs. However, there are significant patches where this segregation was not exercised 100%. It will be interesting to also study dynamics and results of areas with mixes of CTFS and SRI in one farm managing water differently.
- (g) We noted that, introduction of SRI by KPL in the catchment had an advantage on access to loans and extension services to those who undertook the challenge. A study on how much this influenced

increasing or decreasing profitability of the practices could help in adding a layer and advise on unified policy guidance on required support that should go hand in hand with SRI promotion.

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Appendix

Appendix i: Average annual value of input of production - based on 1 ha of farming

N	Farming Inputs	Irrigated SRI	Rainfed SRI	Irrigated CTFS	Rainfed CTFS
A. Land Input					
1	Renting a farm	188.23	161.34	111.77	107.75
Sub Total A		188.23	161.34	111.77	107.75
B. Labour Inputs					
2	Farm Clearing	53.78	43.02	35.65	32.65
3	Ploughing	64.54	64.54	56.85	59.54
4	Blocks preparation	53.93	53.78	37.65	32.27
5	Nursery preparations	26.89	26.86	21.51	13.44
6	Watering the farm	48.40	-	43.02	-
7	Field leveling	80.67	72.60	63.66	64.54
	Uprooting seedlings	37.65	43.02	26.39	24.20
9	Rice transplanting	86.40	86.05	58.02	59.54
10	Weeding with chemicals	64.54	96.80	64.43	53.35
11	2 nd Weeding manual	59.16	75.29	59.16	48.40
12	Bird control	86.05	69.91	53.78	-
13	Harvesting	46.25	64.54	64.54	80.67
14	Threshing	89.81	93.04	103.79	127.52
15	Winnowing	32.54	48.94	81.48	57.01
Sub Total B		830.59	838.40	769.91	653.10
B. Capital Inputs					
16	Seeds	16.13	13.60	19.41	14.03
17	Initiation fertilizer	13.44	35.33	14.68	33.40
18	Pesticides /Insecticides	6.45	5.92	8.07	5.38
19	Weeding chemicals	29.58	30.65	29.58	34.96
20	Boosting fertilizer	91.43	40.33	21.51	14.99
21	Pesticides /Insecticides	6.45	5.92	8.07	5.38
22	Panicle initiation fertilizer	5.93	5.38	27.27	14.99
23	Transportation costs	70.99	116.16	82.82	127.46
24	Storage	34.42	32.27	41.95	32.27
Sub Total C		275	286	253	283
Grant Total Paddy		1,293.64	1,285.30	1,135.02	1,043.70
Grant Total Rice		1,387.76	1,374.04	1,236.13	1,232.46