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Analysis of inputs variability on rice growth stages in Mbeya region

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As rice develops from sowing to harvesting stages require a combination of both natural and non-natural inputs. Thus, at every stage, specific proportions are demanded as aggregates which contribute to the final yields. Understanding these inputs and their impacts on rice yield will help the small scale rice farmers in Tanzania to boost rice yields. This study pursues to (i) characterize rice farmers' in Mbeya Region of Tanzania; (ii) estimate parameters for factors affecting rice along the phenological stages and their influences on growth and yield; and (iii) disclose the perceived factors affecting rice production. Data collected through structured questionnaires, interviews and focus discussions. Data analyses were done by descriptive statistics, Garret ranking techniques, and the Translog Cobb Douglas (CD) model. The descriptive results indicated majority of respondents had ages between 45 and 50 years; only 3% of respondents had informal education and 80% of them own farm size of from 1 to 3 acres. Empirical results show that labour, fertilizer, seeds quantity, pesticide cost, floods, and sunshine duration significantly influenced rice yield. Rainfall was the most influential factors as perceived by farmers. Based on these current findings, suggestions were provided to the responsible policymakers to work on utilizing the potential available from the identified major influential factors to increase farmers' income and increase food security.

Key words: Inputs, rice, growth stage, Cobb Douglass, Mbeya.

INTRODUCTION

Rice is the second staple cereal crop cultivated and consumed more after maize in Tanzania. The crop is grown by the smallholder rural farmers in the lowland and upland ecosystems where almost 90% is under the rain-fed farming. Rice farming apart from providing food, is also a source of employment and income to above 65% rural population (Food and Agriculture Organization, 2017). The area under rice production is approximated to

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681,000 ha accounting for 18% of the total cultivated area in Tanzania (USD, 2019). The rice production has been steadily increasing, and in 2010, Tanzania became the net exporter when the production reached 2.6 million tons. Among the sub-Saharan African countries, the country is ranked second behind Madagascar in terms of rice production level (Famine Early Warning System "FEWS", 2018). Despite the relative potentials for both population and plenty of land available for rice production in the country, production and productivity are far from reaching their full potentials as compared to the other countries in the region. The fact is, while about 92% of land depends on insufficient rainfall water, only 8% is irrigable land (GRiPS, 2013). Less moisture and soil evapotranspiration have become very detrimental factors for rice performance (Kitilu et al., 2019). However, Rugumamu (2014) stresses that apart from less moisture, other environments, non-environmental, and socio-economic factors are the major causes of low rice production in the country. This paper aimed at developing the estimated parameters for major inputs such as labour, rainfall and sunshine, seeds and fertilizer usage, and technological information. Specifically, the study aimed to establish the factor-inputs relationship with the rice phenology.

LITERATURE REVIEW

Weather factors

There are many scholars from different parts of the world who have demonstrated the contributions of various inputs to the development and production of rice crops. For instance, Wu et al. (2016) assert that from 0 to 15 days increase in temperature damages the rice heading. Thus, if the temperature reaches 25°C reduces grain from 2 to 6% of the grain weight. Using the crop model, it was affirmed that maximum and minimum temperature and relative humidity influence rice yield at the vegetative stage, early reproductive stage, and during late reproductive stages (Talla et al., 7. According to Krishnan et al. (2011), an increase in temperature to a less tolerable amount during sensitive growth stages, rice grain loses both weight and quality. Similarly, a study in Japan attributed low rice yield with the risk of cold damage during the reproductive stage (Shimono, 2011). Further, Mahmood et al. (2012), using the regression model equation, found that in each rice growth stage there were different impacts resulting from the variation of temperature and precipitation. Increases in temperature lengthen the growing season and hence cause a decrease in the normal crop year. On the other hand, an increase in rainfall amount also has great influences on the final rice yields (Mostafa et al., 2015). It is subscribed that rainfall water is essential for crop development at the early stages (Zhang et al., 2014). Also, Ntat et al. (2018) insist that rainfall significant influences on rice yield often depend on its degree of variation at each stage of rice growth. Furthermore, Levine and Yang (2014) demonstrate that increases of up to 10% of rainfall boosted rice output by 0.4%. It is also argued that rice benefits aggressive warming trends while maize and wheat stagnate in countries located in low latitude (Iizumi et al., 2017).

Studies also discuss the serious impact of severe rainfalls on rice performance. For instance, it was reported that heavy rainfall and floods affected rice produce in Asia (Khumairoh et al., 2018) and India (Arora et al., 2019) where farmers after realizing the threats, they reacted by purchasing new seeds which could withstand being submerged for a long period. Stressing on the importance of early and late precipitation in crops, it was shown to have a very high correlation with crop yield for conventional corn and soya bean, although for organic, soya bean was negative (Teasdale and Cavigelli, 2017). Further, sunshine and temperature were identified as the main factors affecting rice crops at the maturity stage (Xu et al., 2018).

Labour factor

Labour as an input-factor is as important as both capital and land which for a long time have been regarded as the traditional factors of agricultural production. Labour is required at varying degrees and each stage of rice growth. Also, Chang et al. (2014) noted that labour scarcity has jeopardized rice growth and yield due to rural-urban labour migration in China. Further, Duvvuru and Motkuri (2013) add that due to a decline in family labour in India, it has become difficult for rice handling during the harvesting stages and that mechanization was thought to replace labour requirement is never achieved. It is also revealed that decreases in some panicles and grain numbers which cause poor rice yield was due to insufficient trans-planters which were supposed to perform the transplanting operation at the shortest required time (Liu et al., 2015). This stresses the importance of labour in any farm activity, especially with rice production.

Fertilizer factor

Both organic and inorganic fertilizers are among the essential and common management practices in crop production especially when the soil nutrients are insufficient to support plant growth. Among the essential elements required for the rice to grow are Nitrogen (N), Phosphorous (P), and Potassium (K), however, the plant requires the proper application of this element when there is a deficit in the soil (Kaur and Attwal, 2016; Han et al., 2016). Most of the rice produced in the lowlands requires the application of fertilizers at various growth stages (Han et al., 2016).

Technology and information accessibility

Technology here encompasses an advancement of seed technology such as new seed varieties or improved rice varieties. Applying good quality seed varieties has the greater ability to grow and develop especially at the early stages of seed development. If farmers have good access to quality seeds, there is a possibility to earn higher rice yield. It is very obvious that if farmers keep using local but poor quality seed varieties, they will always have poor rice yields. For instance, Ibrahim et al. (2012) examined the effect of famers' adoption of new rice technologies in Nigeria and found that the application of new rice technologies such as irrigation, modern seed varieties, pesticide, and water management increased farmers' income. Similarly, a study on Rice Intensification System in Tanzania revealed that adopting new rice-producing techniques such as water harvesting, modern seeds varieties boosted production, although, application of agrochemical pesticides was reported to limit aeration and affect the rice root system (Katambara et al., 2016).

Socio-economic factor

The socio-economic characteristics of farming communities play significant roles in crop production. Some studies have already indicated the influence of socio-economic characteristics on rice production. For example, Chavez et al. (2013) examined the impact of socio-economic on the intervention development on rice production in Peru, observing that income was among the factors affecting rice productivity. However, they identified that most of the socio-economic components are not given attention in developmental programs. Socio-economic components for paddy production include age, size of the family, land ownership, and the gender composition (Wilson and Lewis, 2015). In addition to household characteristics, Reddy and Sen (2004) argue that farm size, experiences in rice farming, contact with extension services, and location of farm plots, also have a significant impact on rice production.

MATERIALS AND METHODS

Description of the study area

Mbeya Region is located in the Southern Highlands of Tanzania. It is found between latitude 70 and 90 31' to the south of equator and longitude 320 and 350 east of Greenwich meridian. Rice production is the main agricultural crop in the region and is among the best regions in terms of agricultural yields in Tanzania. Being in the tropical climate that contributes to the performance of crop productions, rice is mainly farmed in the Mbarali and Kyela districts. Mbarali is bordered with Iringa Rural district in the north, Chunya and Mbeya Rural districts to the West and South, respectively. Mbarali receives an average rainfall of 300 to 900 mm per annum starting from December to April as compared to 350 to 800 mm for the Kyela district which is located in the South of the Mbeya Region. The Kyela district borders Makete to the east, Ileje district in the west, and the Republic of Malawi to the south.

Methods and research conduct

The paper is based on data collected from a survey conducted in Mbarali and Kyela districts of the Mbeya Region of Tanzania. The survey was conducted during the farming season from January to March of the year 2018, the period of active farming activities from seedling to weeding. This period was important as it helped us to have physical contact with the intended rice farmers while working in their fields. However, those who were off-field we could meet them in their respective localities. Mbarali and Kyela are the two leading districts in rice production in the region and from each district, two wards were purposively selected. Four villages were again purposively selected where a total of 240 respondents were obtained by a random sampling technique (Table 1). Face to face interviews were used to solicit responses from the farmers. The interviews were guided with a set of written questions. Also, focus group discussions were conducted by involving the selected key personnel, including the villages' leaders, agricultural extension officers, and other important socio-leaders. The questionnaires focused on probing farmers on the different aspects such as socio-economic (Table 2), impacts and contribution of environmental factors on the rice growth stages including the rainfall, sunshine, temperature, winds, and the chaotic events of floods and drought. Also, other aspects of technology and agricultural extension services were probed. All the factors were evaluated based on the farmers' knowledge and experiences.

Descriptive statistics

Socio-economic data and the perceived factors for rice production were analyzed by descriptive statistics from the Stata software and Garret technique. Respondents were required to rank the factors according to their priority such that the highly prioritized factors were assigned number 1=Most prioritized, 2… where the last or less prioritized factor was assigned number 8. Thereafter, the ranking technique developed by Garret and Woodworth (1969) was applied to rank the perceived factors as presented in Figure 1. The Stata software is used to analyze the data by running the Coub Douglas model for parameter estimation.

Empirical model estimation

The main objective of the paper was to assess the relationship between the factor-inputs along the rice phenological process. However, in developing such a relationship we considered different factors including weather components, labour, fertilizer, technology and information, and socioeconomic factors. Thus, we used the Cobb Douglas production model to relate the dependent (rice yield) with a set of explanatory variables. The Cobb Douglass was designed by Charles Douglass many decades ago, and has been widely used in many fields of study including agricultural economics. The model provides the fundamental for relating the output '*Y*' and the explanatory variables: *A* for technology, *K* for Capital, and *L* for Labour as shown in Equation 1.

$$y_i = \left(AK^{\alpha}L^{\beta}\right) \tag{1}$$

Table 1. Distribution of respondents.

District	Ward	Respondents	Mean	%
Mbarali	Mahongole	68	144.6	28.3
	Ruiwa	54	99.24	22.5
Sub total		112		
Kyela	Ikolo	48	88.17	20
	Kajunjumele	70	136.19	29.2
Sub total		118		
Total		240	120.50	100

Source: Field Data (2018).

The assumptions are such that A> 0, 0 < α < 1, 0 < β < 1.

In Equation 1, the *α* shows capital elasticity, defined as an increase of an *α* percent of the output Y when the capital *K* is increased by *1%*; *β* is the labour elasticity, denoting an average increase of *β* percent in the output when the Labour is increased by 1%, and *i* is the individual entity firm or producer or household.

Application of the CD model

The CD model has been used in various fields of study to examine and relate the yields or performance within an industry with the respective inputs. For example, the model was used to analyze technical inefficiencies in dry-season tomatoes. The results indicated that the estimated elasticities and inefficiencies scores were significant (Umar et al., 2017). Wagle (2016) used the CD model in the analysis of the logical relationship between production and labour in Nepal. They found that the sum regression coefficients were less than one (Unit) indicating that the labour factor showed a decreasing return to scale behavior. Furthermore, to optimize water use in China, the CD model was used to develop the relationship between economic benefits and water consumption. The results revealed that water allocation could be effectively achieved under multiple uncertainties and different credibility scenarios (Zhang et al., 2014). The CD model was also used successfully by Hyuha et al. (2007) to estimate the sources of technical inefficiencies by rice farmers where they found that farmers were operating on the profit frontier due to factors such as low education and inaccessibility to extension services. In a broad view, the CD has been used successfully in many studies albeit the application depends on specific study objectives. In this study, we applied the CD model and transformed the traditional model by the used logarithm to obtain the Translog linear model to estimate our parameters.

The CD model setting

From Equation 1, we introduced the weather variable *W,* household socio-economic characteristics S, the technology and information variable *E* in Equation 2. The central idea is the rice yield production affected by many factors other than capital and labour. Therefore, the considered factors are also incorporated in the CD as indicated.

$$y_i = f \ (A, K, L, S, E, W) \tag{2}$$

We rewrite Equation 2a to obtain Equation 3:

$$y_i = f(A\, K^{\alpha k} L^{\alpha l} S^{\alpha s} E^{\alpha e} W^{\alpha w}) \tag{3}$$

Therefore, *A* is efficiency parameter, *αk, αl, αs, αe*, and *αw* are the respective parameters representing the partial elasticities for respective K=Capital, L=labour, S=Socio-economic variables, E=technological and information services, and W=weather. Based on the idea of Wooldridge (2016) and Kmenta (1967), we introduce logarithm (*ln*) in the CD production function to transform Equation 3 to the form of OLS Equation 4. Step-wise regression method was used to run the regression model to obtain the significant variables in Table 2.

$$\begin{aligned} lny_i = \alpha_0 &+ \sum \alpha k\, ln(K_1 + K_2..K_n) + \sum \alpha l\, ln(L_1 + L_2 \ldots L_n) + \sum \alpha s\, ln(S_1 + S_2 \ldots S_n) \\ &+ \sum \alpha e\, ln(E_1 + E_2..E_n) + + \sum \alpha w\, ln(W_1 + W_2 \ldots W_n) + \varepsilon_i \end{aligned} \tag{4}$$

Therefore, the full model is presented as Equation 5.

$$\begin{aligned} lny_i = \alpha_0 &+ \alpha_1\, lnSeed_Q + \alpha_2\, lnFert_Q + \alpha_3\, lnpest_{cost} + \alpha_4 Marit + \alpha_6 labsz + \alpha_5 lab_{trans} \\ &+ \alpha_6\, lnlab_{harvst} + \alpha_7\, lninco_{offam} + \alpha_8\, Info_{seed} + \alpha_9 ext_{floods} + \alpha_{10} ext_{drough} \\ &+ \alpha_{11} lab_{trans} + \alpha_{12} agec + \alpha_{13} educ \\ &+ \varepsilon_i \end{aligned} \tag{5}$$

RESULTS AND DISCUSSION

Socio-economic responses

The results in indicate the overall distributions of the respondents' socio-economic characteristics by age, sex, marital status, education, family size, farm size, and off-farm income. It is shown that the majority of respondents (96.1%) were aged between 25 and 50 years old. This justifies the fact that most of the rice farmers are an energetic adult. The advantages of having this group in agriculture activities provide room for easy technology transfer and adoption, thus, it becomes easy to produce more food to feed the rural community (Kulyakwave et al., 2019b). Also, this indicates that in the study area a majority of youth are engaging in agricultural activities

Table 2. Household's socio-economic distribution.

Variable name	Characteristics	No.	Percent	Mean
Age	Less than 20	1	0.4	16
	20-25	8	3.3	24
	26-31	18	7.5	28
	32-37	37	15.4	35
	38-43	61	25.4	41
	44-49	33	13.8	47
	50-55	34	14.2	52
	Above 55	48	20.0	63
	Total	240	100.0	
Sex	Male	186	77.5	119.0
	Female	54	22.5	121.0
	Total	240	100.0	
Marital Status	Single	10	4.2	106
	Married	230	95.8	121
	Divorced	0	0.0	0
	Others	0	0.0	0
	Total	240	100.0	
Education	Illiterate	6	2.5	143
	Literate	41	17.1	111
	Primary	169	70.4	120
	Secondary	22	9.2	134
	University	2	0.8	132
	Total	240	100.0	
Family size	Less than 2	22	9.2	1
	2-4	200	83.3	2.7
	5-7	18	7.5	5.4
	Above 7	0	0.0	0
	Total	240	100	
Farm size	1-3	194	80.8	1.75
	4-6	40	16.7	4.65
	Above 6	6	2.5	8.12
	Total	240	100.0	
Off-farm income	0-200000	174	72.5	30996.84
	200000-less 400000	45	18.8	302588.9
	400000-less 600000	15	6.3	497333.3
	600000- 800000	5	2.1	7252000
	Above 800000	1	0.4	900000
	Total	240	100	

Source: Field Data (2018).

particularly in rice production. Similar studies elsewhere have reported youth engagement in farming activities. For example, Auta et al. (2010) reported that about 79% of rural youth in Nigeria participate in agricultural production. Also, it was observed that regardless of the many challenges facing youth, the majority of them were engaged in agricultural activities in Nigeria (Akpan et al., 2015). The gender status shows that the majority of the

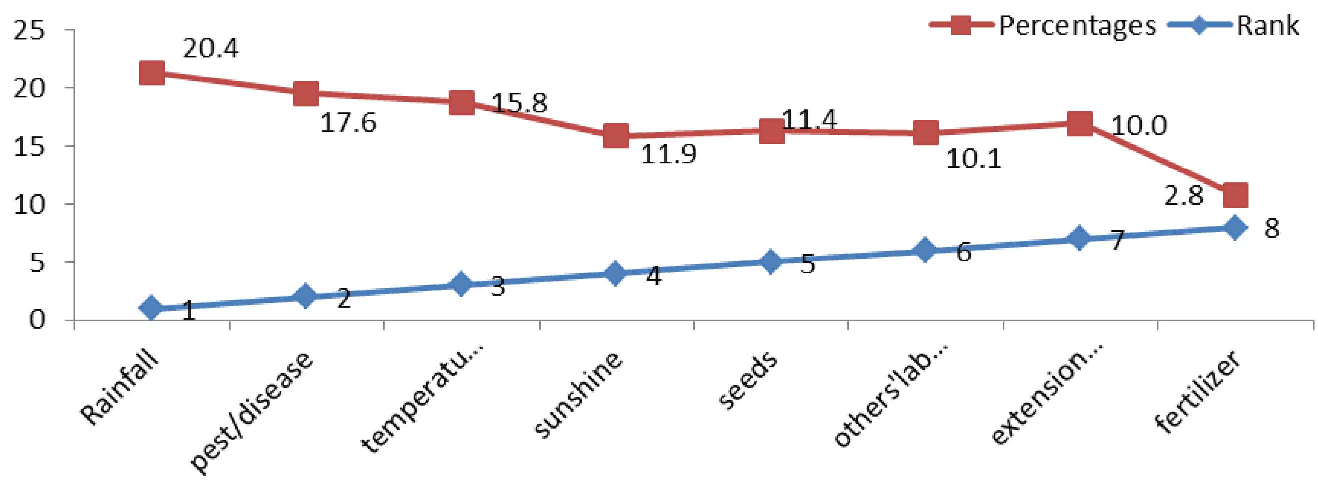

Figure 1. Factors influencing rice production.
Source: Field Data (2018).

rice farmers were male (77.5%) as compared to fewer females (Table 2). This indicates that rice farming in the study region is populated by men. Male dominance in rice farming is not a unique case for the study area as Kim et al. (2017) also recorded the dominance of men by 68.8% in Benue State. However, through focus group discussion, it was revealed that women are mostly involved in the pre-harvesting and post-harvesting stages.

Contrary to current findings, in Philippine, women are more engaged in crop production than men and even their crops' values are higher than values from men (Mishra et al., 2017). Concerning the marital status of the respondents, only a few (4.2%) respondents were single and there was no divorced or widowed respondent. This means rice production is dominated by married couples in the research area. Marriage is advantageous to the farming family as it increases family labour. Also, the challenges of increased mouth to feed activate the respondents to work hard to achieve self-sufficient food. Although George (2015), found that many households in Tanzania face challenges of farming labour, it is obvious that many families utilize the available labour including their spouses.

In Table 2, it is shown that only 2.5% of the respondents had no formal education. This implies that the majority of rice farmers have moderate and reasonable education required to easily access different information about the extension, technology advancement, as well as marketing information. Scholars have a similar opinion that farmers need basic knowledge to access difference agricultural information sources that could help them in farming activities (Adetimehin et al., 2018). Regarding family size, it was shown that most families have 2 to 4 members in their family. However, given the fact that most families utilize family labour to undertake farm operations from land clearing to post-harvest which reduces the cost of production, this number seems to be inadequate to perform the overall tasks as in many families there are also the non-productive members such as children and old ones. A similar observation was given in the work of Karmini and Karyati (2018) that most households had few family members and other members were not interested in non-agricultural activities that caused a labour deficit. It is proposed that at least 7 members in the family could be adequate to perform the entire farming operation as far as small scale paddy production is concerned (Afolami et al., 2012).

Furthermore, reveals that most families (83.3%) have farm sizes from 1 to 3 acres equivalent to 0.4 to 1.25 ha. This scenario is purely an indication of the small scale farming behavior in Tanzania. Smallholder farmers have a low ability to handle larger farms because of the high cost of production including labour deficit, and other challenges such as weather variability. Thibbotuwawa (2014) showed that most rural farmers cultivate small land size and that they face difficulties to obtain technical efficiency. Lastly, Table 2 indicates that off-farm activities were a better alternative for farmers to earn incomes. However, very few (0.4) respondents earned more than 800,000/- Tanzania Shillings. Off-farm income helps to overcome, and support farmers on solving some production challenges including fertilizer cost, hiring labour, and also pesticides. This finding corroborates with Rizwan et al. (2017) who reported that farmers with off-farm income could achieve a technical efficiency of 0.7 to 1.0 as compared to 0.6 to 1.0 for those with non-off farm income.

Perception of the factors influencing rice production

Figure 1 shows important factors identified by farmers regarding their perceptions and the degree of influences from the respective factor. Respondents identified rainfall

Table 3. Description of the variables used in the model.

Variable name	Variable description	Mean	Std. Dev.	Min.	Max.
ydKgha (lny_i)	Rice yield kg per ha	3525	2295	0	11760
Production inputs					
Seed_Q	Seed quantity	20	14	8	76
Fert_Q	Fertilizer quantity	33	30	0	167
pest_cost	Pesticide cost	15836	13842	0	80000
Households characteristics					
maritacode	Marital status of the household head	1508.26	0.2002439	0	1
labsizcode	Labour size	0	1	0	1
inco_offam	Off-farm income	129206	185465	0	900000
Labour cost at growth stages					
lab_seedln	Labour at the seedling stage	45	43	0	300
lab_tranp	Labour at transplanting stage	21	31	0	300
lab_harvst	Labour cost at harvest	221	2606	0	40000
Perception of weather factors					
ext_floods	Extended floods	1	0	0	1
ext_sunshine	Extended sunshine	1	0	0	1
Extension information and technology					
Info_seed	Information of new seed varieties	3	2	1	8

Source: Field Data (2018).

as the major (20.4%) factor influencing rice production in their region. Thus, variations in rainfall could result in negative consequences of crops produced in the Mbeya Region. This is a similar result to what was reported by Powell and Reinhard (2016) on rice and wheat crops in the Netherland. Pest and diseases were ranked second (17.6%) followed by temperature (15.8%), sunshine (11.9%), seeds availability (11.4%), labour (10.1%), extension services availability (10.1%) and the last ranked factors were fertilizer (2.8%). During the discussions, farmers related the occurrence of pests and diseases with events of higher temperatures and less rainfall (Kulyakwave et al., 2019b).

Empirical model estimation results

Table 3 shows the results from the empirical model estimation regarding the factor-inputs relationship to rice growth stages. It is revealed that labour has noticeable roles to play in the rice phenology. At the seedling, stage labour was observed to be very significant with the rice growth at P > 0.000 probability level. This indicates that as labour increases at the rice seedling stage by a 1% unit, it results in an average increase of approximately 72% in the rice yields. It practically shows the importance of labour involvement at the seedling stage (From seed germination to seedlings) which is among the sensitive stages of the vegetative development in rice. Kaur and Attwal (2016) had a similar observation that at the seedling stage the germinating seed is very sensitive and delicate to any environmental stresses such as water, sunshine, pests and diseases, and insects, thus, needs extra attention from farmers.

Regarding labour at the transplanting stage, results show a significant relation to the rice growth stage at the P<0.01 level of probability. This empirical result tells that as labour increases by 1% at the transplanting stage, it causes an average increase of 0.7% of the rice output. The findings denote that the transplanting stage in rice production is an active stage that requires both active and adequate labour to operate for a minimum duration of time. Liu et al. (2015) insisted that delay in rice transplanting operations as a result of insufficient rural labours in China caused a negative response in growth during photosynthesis, productivity, and grain yields. Thus, reasonable operators have to be available to meet the minimum timing required for seedlings preparation for the transplanting process.

The results further reveal that labour at the harvesting stage was significant and negative at P > 0.1 level of probability. This means there is an average decrease of 34% in the rice output when labour is added by 1% during the harvesting stage. In the research area, rice is harvested by using either reapers or sickles (for majority producers) or hired combine harvesters. These developments of technology have played a great part in harvesting labour reduction albeit it did not reflect on the cost of harvesting as it was the case in China, Vietnam, and Malaysia (Global Rice Science Partnership (GRiSP), 2013). The rice seeds variety use was significant to rice production at P>0.02 level of probability. As an important input in rice production, both quality and the right amount of seeds varieties are required for optimal output. It was revealed that the increase of local seed variety usage by 1% of a required amount per ha averagely decrease of 24% in the rice yield. This indicates that failure to access improved quality seeds and lack of knowledge of the right quantity of seeds per ha has a negative implication to farmers. A similar observation is reported by Sapkota (2015) that due to poor access to education and extension services in Nepal farmers tend to overuse seeds which adds the cost of production.

Regarding fertilizer usage, the result in Table 3 indicates that fertilizer quantity was very significant at P>0.000 probability level. However, the direction of the fertilizer coefficient was negative. This proclaims that as the amount of fertilizer increased by 1%, it leads to an average increase of 24% in the rice yields. However, the optimal amount of fertilizer needs to be observed by farmers. The fact is an increase in fertilizer is translated to the increase in production cost to farmers which has a direct impact on the accrued profit. Therefore, there is a tendency of over-use fertilizer with an expectation that there would be an increase in output without consideration of the associated costs. Sun et al. (2019) found that the overuse of chemical fertilizer is common in China. This trend also agrees with Ibrahim et al. (2018) who insisted on proper fertilizer application to promote farmers' income and address food security in the Sahelian. The pesticide costs incurred by farmers were very significant at P>0.000 probability level (Table 3). This indicates that pesticide costs affect farmers' rice output negatively since the coefficient is negative. It means, as the expense increased by 1% to purchase a liter of pesticide, there is an average decrease of 74.3% in the rice yields. In the study area, farmers pointed out that pests and disease are one of the challenges they face especially when the temperature is very high and there is less rainfall. Therefore, since the pesticides are solid at a relatively higher price most farmers fail to afford.

On the other hand, sunshine shows a very high significance with rice yields at P>0.000 probability level. Conversely, it depicts that increases in sunshine duration by 1% of every hour result to an average increase of 87% in the rice yield. This indicates that an increase in sunshine duration was important for rice growth as well as for rice yields. These findings concur with other studies that identify sunshine as an important factor for rice production in the area (Dabi and Vk, 2018; Hu et al., 2019). On the contrary, Jiayu et al. (2018) report sunshine duration to have no influence on rice yield in Eastern China. Table 3 indicates that high rainfall (floods) was significant with rice production at P>0.000 probability level. Although flood is one of the important factors determining rice production in the research area, it has a negative direction due to its negative coefficient especially when farmers lack quality seeds that can withstand high rainfall. Thus, it can be expressed that an increase of flood occurrence decreases by 55.2% in the rice yields. This confirms the report by the Global Rice Science Partnership (GRiSP, 2013) that almost 16 million ha of rice were damaged by floods in Asia. Similarly, Powell and Reinhard (2016) observed that extreme floods were detrimental to crop yields in the Netherland.

The study shows that information about seed technology (Table 3) significantly influences the rice output in the region. It was observed that when information concerning seed technology is more accessed by 1%, there was an average increase of 17% in the rice yields. This means that farmers are exposed to different information sources regarding new seed varieties, and seeds availability enables farmers to utilize seeds for better yields. The marital status of the households' head was also shown to be significant with rice production (Table 3). Rice production is considered a labour-intensive activity; therefore, being married adds the labour force in households. On the other hand, the findings showed that labour size significantly influenced the final rice yields in the region. However, the coefficient of labour was negative meaning that there is a decrease of 33% in the rice yields when the labour size is increased by 1%. This trend could be attributed by a smaller ratio of farm-size to labour, and also the use of mechanization and pesticides which displaces the labour force. For instance, Duvvuru and Motkuri (2013) argued that due to technology advancement, the increase and decrease in labour in the same direction depend on whether it is casual or family labour.

The results in Table 4 indicate that income earned by households from off-farm jobs significantly influence rice production in the region. However, our results show the off-farm income coefficient is negative meaning that as the farmers earn more income from off-jobs, it influences the rice output negatively. This means there is an average decrease of 20.1% in the rice yields when income from an off-farm job is increased by 1%. The main reason for this is that as farmers earn higher off-farm incomes, more attention both time and resources are given to the off-farm jobs and less attention is given to their rice farms. Therefore, it affects most of the farm operations resulting in poor rice yields. Further, the prevailing impacts of climate change and weather variability have made rice crop production vulnerable to shocks such as droughts, floods, pests and diseases which threatening farmers to invest their earned off-farm capitals in crop production. Our findings agree with Diiro (2015) that off-farm farmers reduce farm level efficient (0.39) as compared (0.43) to farmers without off-farm

Table 4. OLS regression result for yield Kg/ha with the independent variables.

lny kg/ha	Definition of variables	Coef.	Std. Err.	t	P>t	Sig.
lnlab_seedln	The logarithm of the lab at seedling	0.716	0.039	18.150	0.000	***
lab_trans	The logarithm of the lab at the transplanting stage	0.007	0.002	3.890	0.006	**
lnlab_harvst	The logarithm of Labour at harvest stage	-0.340	0.149	-2.290	0.056	*
lnSeed_Q	The logarithm of seed quantity	-0.240	0.078	-3.070	0.018	**
lnFert_Q	The logarithm of fertilizer quantity	0.242	0.076	3.180	0.000	***
lnpest_cost	The logarithm of pesticides cost	-0.743	0.045	-16.640	0.000	***
ext_sunshine	Dummy variable of excess sunshine	0.872	0.061	14.230	0.000	***
floods	Dummy variable floods	-0.552	0.053	-10.440	0.000	***
Info_seed	Logarithm for seed technology information	0.170	0.027	6.380	0.000	***
maritacode	Dummy for marital status	0.097	0.113	0.860	0.000	***
labsizcode	Dummy variable for Labour size	-0.329	0.065	-5.062	0.000	***
lninco_offam	Logarithm for off-farm income	-0.201	0.045	-4.490	0.003	**
_cons		21.935	1.387	15.820	0.000	

Prob > F = 0.0000, R^ = 0.9935, Adj R^ = 0.9823.
Source: Field Data (2018).

income. An increase in off-farm income also caused farmers to lease out their farmland (Zou et al., 2020). Off-farm income helps manage farm risks (Akhtar et al., 2019). Similarly, it is reported that off-farm income was detrimental to crop production but with increases households' level diversifications to other means of production (Ochoa et al., 2019).

Conclusion

The study has demonstrated the impacts of various inputs factors on different rice growth stages and the aggregate rice yields in the Mbeya Region of Tanzania. The identified input includes environmental, non-environmental, and socio-economic factors. Among the inputs, labours seemed to influence rice at different growth stages such as at seedlings, transplanting, and harvesting stages. Fertilizer and the quantity, and pesticides were found to have a direct implication on added costs to farmers. That is to say, the application of these inputs could cause a greater impact and decrease rice growth, yields, and rice revenues. Likewise, flood events affect rice yields negatively as opposed to sunshine which averagely increases rice yield. Lastly, it was observed that farmers' off-farm income affects negatively rice performance and yields.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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