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Effect of cropping pattern and agronomic practice on Maize productivity among smallholder Farmers in Kilosa District, Tanzania

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Abstract

The study was investigating the influence of cropping pattern and agronomic practice on maize yield in Kilosa District, Tanzania. The simple random probability sampling technique was employed to select 200 respondents. The survey questionnaire was employed for primary data collection. Data was analysed by multiple linear regressions. The results of suggest that 61% of the respondents were female, most of respondents had 18 years to 25 years seems to be more involved maize farming, 57% of respondents had Primary education and 74% of respondents were married. The finding further revealed that 65% of the respondents came from the household with 1-5 members. The finding also confirmed that cropping pattern where smallholder farmers planted maize with legume (cowpeas, pigeon peas and beans) increases maize yield by 30.43% compared to smallholder farmers who planted single crop. Moreover, it found that, relay cropping and strip cropping were positive and significantly increased maize yield by 22.68% and 22.36% respectively. It is also found that agronomic practices such as weeding, spacing and manure application had positive effect on maize yield, increases maize yield by 28.12%, 25.26% and 37.14% respectively. Unfortunate, smallholder farmer planting crop along slope land particularly high elevation experienced decline of maize yield by 53.74% compared to smallholder famers at lowland. The study however, recommends that cropping practices be promoted where maize planted with legume.

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Introduction

Agriculture is a mainstay of economy and serving more than 70% of population for their livelihood in Tanzania (Epaphra and Mwakalasya 2017; Mkonda and He, 2016). It contributes to food security, employment and foreign currency to the country. Maize contributes 31% of the food produced in Tanzania and constitutes more than 75% of cereal consumed in the country (Msuya *et al.,* 2017). The estimated per capital consumption of maize is approximately 128 kg per annum (Peter *et al.,* 2013). Closely to 400grams eaten per day per person in Tanzania. The average country consumption is projected as over 3 million metric tons per annum (Suleiman *et al.,* 2017). Maize provides around 34-36% of regular daily calorie intake (Kinabo *et al.,* 2016). According to Ouma *et al.,* (2014), food balances sheet indicates 60.8% of maize produced countrywise in 2013 was consumed by human and 20.6% of it in average wasted. The animal feed represents 16.1% of maize produced while 0.5% of it channeled to food processing.

Maize is the leading cereal crop and widely cultivated by smallholder farmers with average farm size ranging between 2 and 3 hectares in countrywise (Lyatuu *et al.,* 2016). Although, aggregate production trend of maize at national level increases, expansion of farm land and cultivation of new virgin land are well pronounced. This not only affect its production efficient and effectiveness but also it creates land scarcity and conflicts as they are expanding for maize production. An increase of land under maize cultivation has been pushing up the national production (Kadigi *et al.,* 2020; Vyamana *et al.,* 2021). The land for maize production has almost increased more than two times from 1990 to 2012. This may not be a sustainable solution for increasing maize production due to land is a scarce resource and Tanzania population growth pops up at 3% annually (Uisso and Tanrıvermis, 2021). Under such situation, more land is needed for various economic activities in in the country.

Expansion of smallholder farms to increase maize production is not a solution to transform smallholder farmers. Smallholder farms are highly characterized by low maize yield (Julien *et al.,* 2019).

This clearly associated with such major drivers include soil infertility, use of maize local seeds, climate change and poor extension service. The decline of soil fertility is largely contributed by monocropping and poor soil maintenance (Kebede, 2020). It is also crop residue burning practice and taking away farm residue farm field during land preparation (Bajracharya *et al.,* 2021). Limited use of improved practices results in low crop yields because the currently techniques adopted by smallholder farmers are not effective in optimizing maize production. Also, most of smallholder farmers not following the proper agronomic practices such as use of manure, timely planting, timely weeding, pest control, use of improved seeds and minimal use of fertilizers (Awodumila *et al.,* 2020). In many virgin lands, plant nutrient taking out is frequently observed, with monocropping cropping that projected to draw the plant nutrients at rates 6 to 7 times greater than the rate at which plant nutrients are replaced (Gebresamuel *et al.,* 2021). The practice of continuo cultivation of single crop which also involved burning crop residues and removal of it, it accerates and deteriorates the soil nutrients in the farm land.

Improving the maize yield particularly maize is one of the strategic programs in the country for agricultural productivity enhancement. The adoption of natural farming and agronomic practices for managing the soil fertility sustainably is frequently considered as critical approach in addressing soil fertility decline and increases the maize yield (Ogada *et al.,* 2021). Cropping pattern and zero tillage have appeared as an alternative to monocropping which deplete the soil fertility. The basic principle such as minimizing soil disturbance, maintaining permanent soil cover, intercropping and practicing crop rotations are essentially for smallholder farmers to enhance soil fertility and increases the maize yield. According to found that cropping pattern has significant role in improving soil fertility, thus increase the yield of crops (Sahruzaini *et al.,* 2020).

Different empirical literatures have been pointed out the existence of agronomic practices on farm crops include maize crop grown in Tanzania.

Such empirical literatures include; Nonga *et al.* (2011) who found that smallholder farmers used a lot of pesticides, high fertilizers, local and improved seeds in farming.

The farm weeding is usually seen that smallholder farmers used hand hoe to weed and may be done once. Similarly, the study by Ngowi *et al.* (2007) shown a serious use of pesticides where irrigated farming is practiced and highly use of pesticides among smallholder vegetable farmers in Northern Tanzania. Kaliba *et al.* (2018) revealed that Smallholder farmers are oftenly used improved varieties and spacing of 90cm x 50cm for seed per hole or 75cm x 60cm for two seeds per hole which makes approximately 44,444 plants per hectare. Temu *et al.* (2011) found that age, marital and intercropping of maize with leguminous influence yield per acre. Similarly, Kaliba *et al.* (2020) investigated the intercropping maize with cowpeas and found that yield maize was increasing by 27% in intercropping when compared with monocropping of maize. From the literature reviews, it is revealed that varied and diverse researches have been done in the field in an efficient manner particularly in Developed countries, Developing countries and Tanzania as well. It is evident that many researches related to cropping pattern have been done in different angles from different variables but limited research works were done in Tanzania. Developing countries have higher degree of variation in its cropping pattern, crop combination and crop diversification.

The main argument for cropping pattern practices is to improve and conserve soil fertility and use them sustainably for increasing the maize yield. Cropping pattern and agronomic practices are thought to be among factors influencing the maize productivity. Studies include Suvi *et al.* (2020); Justin (2015); Adam *et al.* (2020); Rowhani *et al.* (2011) identified underlying factors for delined maize yield in Tanzania. However, little is known to whether cropping pattern practices have significance association with maize yield. For this reason, the study bridges this gap of knowledge by evaluating the effect of cropping patterns on maize yield in Tanzania.

Material and Methods

The research was conducted in Kilosa district which is considered as a potential in agriculture with production of various crops. The district has a typical agricultural economy with more than 90% of their population rely on agriculture. The agricultural sector alone contributes more than 80% of the district income. The district is characterized by semi humid climate, receiving an average annual rainfall of 800mm distributed in eight months (October to May) with temperature ranges from 18°c in hills to as high as 30°c in the low lands. The soil is characterized by slightly drained and black cracking clays.

Research Design, Sampling and Sample Size

The study explored the cross-sectional design as data were collected at single point in time. The purposive non-probability sampling enables researcher to choose district, wards and villages that provided appropriate information for crops cultivated and climatic favorability for crops. The respondents were chosen using simple random probability sampling where everyone in a study population has equal chance to be chosen to represent a population in the study area. The smallholder farmers cultivating maize with other crops were treated as respondents. According Dhokhikah *et al.* (2018) proposed a Slovin's formula for determine the sample size. The following is the formula used in sampling estimation from population selected.

$$\eta = \frac{N}{N \times d^2 + 1}$$

Where; η = number of Sample

N = Total number of populations = 4744

d = error margin = 0.0705 (7.05%)

$$\eta = \frac{4744}{4744 \times 0.0705^2 + 1} \approx 200$$

η = 200

The sample size was 200 respondents.

Data Collection Tool

The researcher made use of questionnaires as a way of collecting data in order to be able to address the objectives of the research. The questionnaire was made simple and allowed the researcher to administer to respondents for collecting data from small holder farmers.

Analytical Model and Data Analysis

Multiple Linear regressions is a statistical measure that attempts to determine the strength of the relationship between one dependent variable and a series of changing variables known as independent variables. Gujarati and Porter (2009) suggested that Ordinary Least square method. Several authors presented the strength and weaknesses of various techniques used in the relationship measurement. The following multiple regression describing the relationships between dependent variable and the explanatory variables were therefore postulated, where β's are regression coefficients and Ɛ is an error term.

$$Y=\beta o+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6+\beta_7X_7+\beta_8X_8+\beta_9X_9+\beta_{10}X_{10}+\beta_{11}X_{11}+\beta_{12}X_{12}+\beta_{13}X_{13}+Ɛ$$

Where Y= Maize productivity (Tons Per ha)

X_i= Variable

β_i= Coefficient of variable

Where i=1, 2, 3…

X_1= Gender, X_2=Age, X_3=Education, X_4= Marital status, X_5=Household size, X_6=Cropping pattern, X_7=Relay Cropping, X_8=Strip Cropping, X_9=Farm slope, X_{10}= Extension service, X_{12}=Weeding, X_{11}=Plant pacing, X_{12}=Manure.

Data from survey questionnaire was fed into SPSS software before transferred to stata for analysis of econometric regression. Linear regression Model was used to analyze the effect of cropping pattern and agronomic practice on maize yield.

Results and Discussion

This section explains procedures which were followed in order to get results and presents results as well as discussion of the findings of the study. On analysis, the descriptive statistic was used to analyze demographic characteristics and li8near regression technique was used to analyze influence of cropping pattern on maize productivity. Meanwhile, Multicollinearity, Heteroscedasticity and Model specification error were tested for the entire variables to obtain more consistent parameters for the model.

Demographic Characteristics

The results of descriptive statistical analysis were used to analyse the demograpgic characteristics of the smallholder farmers in study area. This analysis focuses on gender, age, education, marital status and household size. To make analysis simple and clear for understanding the distribution of demographic, Pie chart and Bar chart were used to present the results.

Gender of Respondents

The gender of respondents based on male and female were presented in each village where frequency, percentage and overall percentage indicated in Fig. 1.

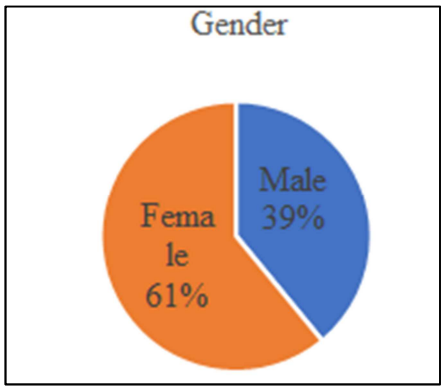

Fig. 1. Gender of Respondents.

Fig. 1 revealed that majority of respondents were female. It was almost 61% of the interviewed respondents were female. This result signifies that female respondents were more active than male respondents in farming. This means male were less active in farming activities in the households. The present finding contradicts with Van Tran *et al.,* (2019) who found that male dominated in rice farming.

Age of Respondents

The age of respondents was categorized into six classes as indicated in Fig. 2.

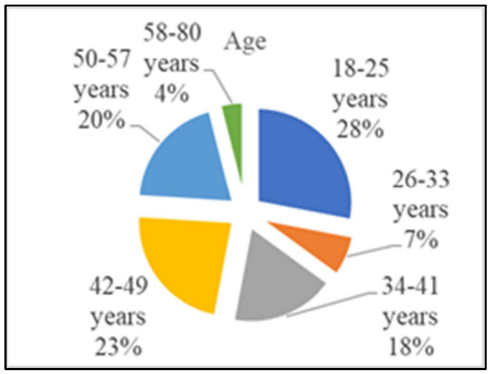

Fig. 2. Age of Respondents.

The Fig. 2 confirmed that 28% of interviewed respondents had dominated the maize farming in the area. The finding implies that majority of respondents had 18 years to 25 years seems to be more involved in agriculture particularly in maize farming. This means elder people were less active than youth in maize farming. This also entails that young people or youth in the area were the leading group in maize farming as majority of the population in Tanzania is occupied by youth.

This was good for Tanzania as majority of graduate would be expected to make their way for to agriculture in order to reduce unemployment rate in Tanzania but also increase agriculture productivity. The more youth engaged in agriculture indicates a good index to improved agricultural production because farmers' productivity is deemed to decrease as they age. The finding also contradicts with Jones *et al.* (2011) who found that majority of youth are active in farming.

Education of Respondents

The education level of respondents was categorized into five in each of four villages. However, the five categories of education were none or informal education, standard seven, form four, form six, and college/university as shown in Fig. 3.

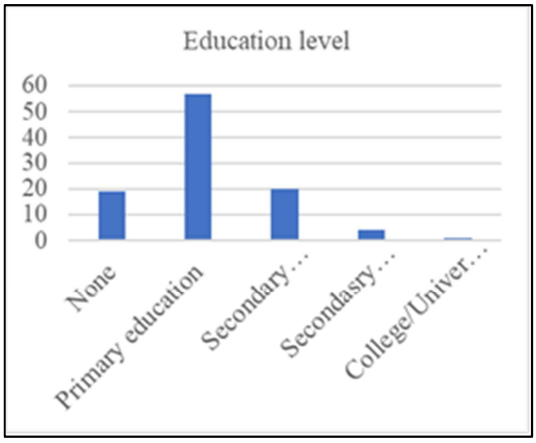

Fig. 3. Education of Respondents.

The Fig. 3 shown that 57% of interviewed respondents had standard seven. This finding revealed that majority of the smallholder maize farmers had primary education which enabled them to aware best agronomic practices in maize farming as well as recommended practice. This has great positive effect on crop productivity among smallholder farmers because education found to have higher payoff to productivity in modernizing agriculture than traditional agriculture knowledge. Education has significant role in improving crop farming (Mango *et al.,* 2018). This finding concur with Wang *et al.* (2017) who argued that education is expected to enhance adoption of improved practice in crop farming.

Marital Status of Respondents

The marital status of respondent in study area where the distribution falls into single, married, window and divorced respondents as per Fig. 4.

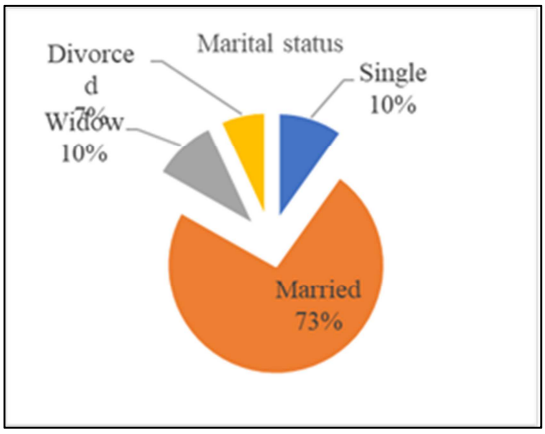

Fig. 4. Marital Status.

The result in Fig. 4 reveals that 74% of interviewed respondents were married in the area. This finding entails that married has great effects on maize farming as married couple may have great manpower in maize farming of relatively greater than single, widowed and divorced due to different in manpower and decision making. The married couple however drives the majority in maize farming in the area. Similar findings was also noted by Abdallah *et al.* (2021) who found that majority of smallholder farmers came from marriage couple were cultivating food crops in rural area of Kenya.

Household size of Respondents

The household size of respondents was distributed into category with interval of 4 members of households as shown in the Fig. 5.

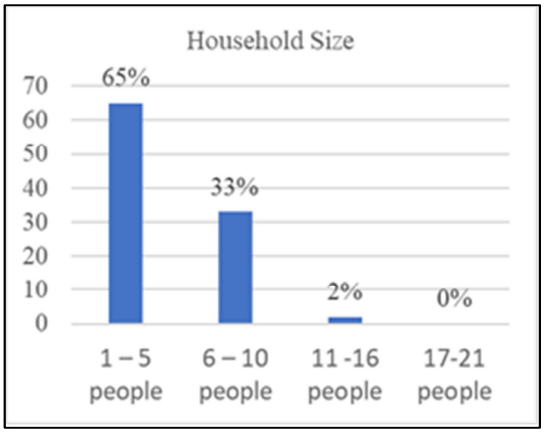

Fig. 5. Household size.

As per Fig. 5, it was found majority about 65% of the respondents had households with 1-5 members in households in the study area. This finding implies that members in household provide more manpower for smallholder farming provided that they can participate in maize farming. In most of the rural areas, crop farming is a main economic activity and that drive the economics of the households. In this aspect, members of the household provide the labour force to most of the farming activity.

Multiple Linear Regression Results

The result was presented in table 1 focused on regression analysis used to analyse the influence of cropping pattern on maize productivity among smallholder farmers in Kilosa district. In order to trust regression results and results, Multicollinearity, heteroscedasticity and model specification test were performed to check whether important assumptions were not violated. The result of regression analysis indicates that model has goodness of fit, since F test (16, 183) was 21.56 with P (0.0000) < 1%. This indicates that explanatory variables together have relationship with outcome variable. The R - squared was 0.6245 (62.45%). This implies that cropping patterns and other factors included in the model together are jointly explain the variation in maize yield by 62.45%

Cropping Pattern and Maize Yield

The practice of planting together more than one crop in a piece of land with consideration of plant spacing and line is normally termed as cropping pattern. In developing country, the practice is common under smallholder farms. Under this study, cropping pattern was found to be positive and statistically significance at 1% level of significance.

Table 1. Multiple Linear Regression Estimation Results.

Ln Maize yield	Coefficient	Std. Err.	T-test	P>t
Gender Dummy	-0.1098	0.0851	-1.29	0.1990
Ln Age (Year)	0.1368	0.1083	1.26	0.2080
Education	0.2717	0.1290	2.11	0.0370
Marital status	0.1969	0.1009	1.95	0.0520
Ln Household size	0.1487	0.0896	1.66	0.0990
Cropping pattern	0.3043	0.1009	3.02	0.0030
Relay cropping	0.2268	0.1030	2.20	0.0290
Strip cropping	0.2236	0.1002	2.23	0.0270
Farm slope	-0.5374	0.1340	-4.01	0.0000
Extension service	0.1118	0.1014	1.10	0.2720
Weeding	0.2812	0.0948	2.97	0.0030
Plant Spacing	0.2526	0.0875	2.89	0.0040
Manure	0.3714	0.1025	3.62	0.0000
Constant	4.9228	0.4891	10.07	0.0000
Number of Observation	200			
F (16, 183)	21.56			
Prob > F	0.0000			
R-squared	0.6245			

This finding reveals that crops planted in the same piece of land at particular growing season increases the maize yield by 30.43% per hectare as compared to smallholder farmers who planted one crop. Thus, planting one or multiple crops at the same farm during growing season has advantage of improving soil fertility especially when planted with leguminous crop. The leguminous plant has nodes which through bacterial fixation process release nutrients such as nitrogen which is highly needed in large quantity by plant. This nurturing the maize plant to produce more maize grains on cobs. The present finding also confirmed by Bitew *et al.* (2021) and Li *et al.* (2019).

Relay Cropping and Maize Yield

The tendency of planting second crop in the same field before first crop harvested is basically known as relay cropping and has economic benefits in term of resource utilization. The practice makes use of resource efficiently and effectively. This study found that relay cropping was positive and statistically significance at 5% level of significance. The result suggests that planting maize with another crop in the same land and different time at growing season increase yield by 22.68% per hectare in comparison with those planted single crop. Planting maize with another crop before harvesting at the same land reduces competition among plants in the farm.

The maize plant takes advantage of nutrient release by common bean plant and grows vegetatively. The finding contradicts with Kermah *et al.* (2019) who observed that relay cropping of maize with cowpeas had negative implication where maize yield reduces by 0.64 tons per hectare. Similarly Raza *et al.* (2019) reported the maize yield loss when planted with soybean.

Strip Cropping and Maize Yield

Strip cropping a method that control and conserve soil while preventing soil erosion. The practice involves planting crops in alternative line in the same field, it look like contour. Our study observed that, strip cropping was positive and statistically significance at 5% level of significance. The result indicates that strip cropping had positive relationship with maize yield. It further reveals that planting maize with bean in alternative line in the same land at growing season increase maize yield by 22.36% per hectare. The planting more than one crop in alternative line and in the same land during growing season has advantage of reducing soil reaching and improving soil fertility especially when planted with leguminous crops. The maize plant produces more maize grains on cobs. The finding conquers with Głowacka (2013) who found that maize and bean planted in row with considerable spacing pattern shown maize yield has significantly increased. Also, Khokhar *et al.* (2021) found increase of yield by 24% higher than sole cropping.

Farm Slope and Maize Yield

The farm land that smallholder farmer cultivates on the sloping land needs much attention to control water run-off and soil erosion. Thus, it controls the soil fertility and improves the crop yield. In this study, result has shown that farm slope was negative and statistically significance at 1%. The farm slope had negative relationship with maize yield per hectare. The result indicates that a farm located at sloping decreases the maize yield by 53.74% per hectare as compared to farm slope located flat land. In fact, farm at sloping land experienced the run-off of nutrients which washed away by water running over the surface of the farm land. This may carry away top soil contains the soil nutrients and other organic matters necessary for nurturing the maize plant. Although, smallholder farmers were advised to use contour ridge to control run-off of water which wash away soil, however smallholder farmers are reluctant to such practice in Tanzania, as result soil nutrients washed away. This weakening the maize plants vegetative growth due to lack of soil nutrients. The finding of the study conquers with Zhang *et al.* (2012) who found positive association between maize yield and elevation. This further confirmed that maize yield increased with increasing elevation.

Weeding and Maize Yield

The weeding was positive and statistically significance at 1%, signifying that, weeding had strong relationship with maize yield. This result suggests that weeding practice done more than one times increases the maize yield by 28.12%. The practice reduces competition among unwanted plants and maize plant in terms of nutrients, air and light which necessitate the plant vegetative growth. It also allows the application of fertilize to be well utilized by intended plants rather than unwanted plants or weeds. This makes maize plant to grow well and produce many grains in the cob, hence increase maize yield per hectare. This finding is strongly supported by a number of studies like Chipomho *et al.* (2021); Ijoyah *et al.* (2015); Mashavakure *et al.* (2019).

Plant Spacing and Maize Yield

Among important factors for yield performance is plant spacing which principally varies according to each crop. The study analyzed the effect of plant spacing on maize yield. The plant spacing was positive and statistically significance at 1%. The recommended plant spacing had positive association with maize yield. This finding suggests that smallholder farmers who use recommended plant spacing increase maize yield by 25.26%. It is obvious that, recommended plant spacing reduces competition among plants in term of nutrients, air and light. Thus, maize plant grows at good condition and increase crop vegetative growth healthier and produces many gains on the maize cobs. This finding conquers with Koirala *et al.* (2020) who found that,

higher maize yield was reported at spacing of spacing 60×25cm. This is recommended for smallholder farmers to adopt in order to maximize maize yield.

Manure and Maize Yield

The manure was positive and statistically significance at 1% level of significance. Since p value (0.000) of manure was less than 1% level of significance. The manure had positive relationship with maize yield per hectare. The result reveals that smallholder farmer who applies manure increase maize yield per hectare by 37.14%, provided that other factors remained constant. Possible explanation was that application of manure improves soil fertility especially when due to organic matters present in the manure. When manure decomposed, it releases nutrients particularly nitrogen which needed in large quantity by plant. Hence, maize plant takes advantage of nutrient release by manure to grow healthily. This nurturing the maize plant to produce more maize grains on cobs. This finding conquers with Githongo *et al.* (2021), animal manure significantly improve maize yield and soil nutrients.

Conclusion

The study evaluated the effects of cropping pattern and agronomic practice on maize yield. The analysis of current cropping patterns and agronomic practice were significantly improving the maize yield. the finding suggests that relay cropping increases the maize yield by 22.68% while strip cropping increases maize yield by 22.36%. This tells us that, higher yield observed from relay cropping than strip cropping. The finding also shown that, declined maize yield was recorded on higher elevation of land on sloping land. The finding suggests that weeding practice done more than one times increases the maize yield by 28.12%. It is similarly, recommended plant spacing increase maize yield by 25.26% while manure increases maize yield by 37.14%. In order to increase maize yield, smallholder farmers are advised to practice the relay and strip cropping on their farms. As far as smallhder farmers practice relay and strip cropping, maize yield increases as soil becomes more fertile due to nitrogen fixation especially when maize planted with legume. If manure, timely weeding and recommended plant spacing applied to farm land, smallholder farmers are expected to record higher maize yield on their farms.

Recommendation

The study emphasizes relay cropping, strip cropping, manure application, timely weeding and plant spacing should be promoted. Smallholder farmers be advised to plant maize with other crop particularly leguminous crops in the same farm at growing season. There should be an approach to impart knowledge on smallholder farmers about agronomic practice because extension service provided by extension agent has proven no effect on maize yield. Alternative approach such as like mobile extension service technology may be adopted.

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