Usage of Climate Smart Agriculture Practices: An Analysis of Farm Households' Decisions in Southern Highlands of Tanzania

[1]*Bongole A.J., K.M.K. Kitundu[1] and J. Hella[2]

[1]Sokoine University of Agriculture, Department of Policy Planning and Management, P.O. Box 3000, Chuo Kikuu, Morogoro Tanzania.
[2]Sokoine University of Agriculture, Department of Food and Natural Resource, P.O. Box 3007, Chuo Kikuu, Morogoro Tanzania
*Corresponding author's e-mail: *bongoleaj@gmail.com*

Abstract
Developing countries in Sub-Saharan Africa are facing challenges in agriculture development due to change in market conditions, food demand and climate. Climate change causes a major threat to agricultural production and food security in Tanzania, and Climate-smart Agriculture (CSA) is crucial in addressing the potential impacts. The study used cross-sectional data from 1443 farm households in the Southern Highlands of Tanzania to analyse factors that determine probability of using multiple combinations of Climate-smart Agriculture practices (CSA-practices) (i.e., crop rotation, crop residue retention and intercropping). The multinomial logit model was applied to examine the determinants of using multiple combinations of CSA-practices. The analysis of factors that influence farm households' decision to use CSA-practices revealed that production diversification, gender and livestock ownership were found to have a positive and significantly influence on the usage of combination of crop residue retention and intercropping (C0R1I1). In addition, education level and gender of the household head had positive significance in the usage of combination of crop rotation, crop residue retention and intercropping (C1R1I1). This comprehensive study is significant for a finer understanding of the synergistic effect of interrelated CSA-practices. The study calls for policy makers to enact policies and plans that promote CSA-practices as a combination, including other interrelated practices to upscale CSA-practices usage while harnessing the synergies between them.

Keywords: CSA-practices; usage; crop rotation; crop residue retention; intercropping

Introduction

Climate change is one of the biggest challenges to food security systems in the 21st Century (IPCC 2014). The global population have to deal with the impact of climate change as it is widely accepted that the ability to control the pace of climate change by keeping the temperature change with 2°C threshold for long run is now difficult (ibid). The major consequences of climate change include the unreliable precipitation, floods, drought, storms and landslides which lead to loss of human life, decline of crop and livestock yield, soil erosion, etc., and hence negatively affect household food security (Byishimo, 2017; Goglio, *et al.,* 2018).

Developing countries in Sub-Saharan Africa (SSA) are facing challenges in agriculture development due to change in market conditions, food demand and climate. It is predicted that the mean annual temperature of the extensive area in the middle of the 21st Century will be 2°C higher than during the late 20th Century with an increase of drought incidence and unpredictable precipitation (IPCC, 2014). The impacts of these changes are expected to increase pests and diseases for crops and livestock, affect water supplies, adversely affect biodiversity, hence food insecurity (Grossi *et al.,* 2018). In this case, climate change and agriculture seem to be interrelated in such a way that climate change has direct positive or negative effects on agriculture through changes in temperature and precipitation while agriculture also affects climate through emissions of greenhouse gases (ibid). It is estimated that agriculture through use of fossil fuels cultivation of organic soils and poor management of inorganic fertilizer contributes up to 30 % of the total global greenhouse gas emitted (Garnett 2012).

Tanzania is among the most vulnerable countries to climate change threats. Studies by Mkonda and He, (2017); Mashingo, (2010) shows that, since 1960 there is an increase of 10 °C annual temperature and decrease of rainfall at an average rate of 2.8 mm per month. An increase of extreme events such as drought, floods and storms with a negative impact on food crop production and a serious impact on food security especially in the rural farming households are also predicted (Mbilinyi, *et al.,* 2013). In addition, the negative impacts of climate bring about socio-economic impact on people especially in poor farming communities. Rural Tanzanian's smallholder farmers, who are already bearing the brunt of climate vagaries, are among the most exposed to the risks associated to climate change (Mashingo, 2010).

Given adverse effects of climate change, farmers in Tanzania especially in Southern Highlands have been making changes to their agricultural practices but the usage rate is still low (Mkonda and He, 2017). These changes are targeting both crop and livestock production which include usage of improved seed varieties, crop rotation, animal breeds, soil and land management practices, water conservation practices, and improved fodder production among others (Capone *et al.,* 2014). These practices referred to as climate-smart agriculture are expected to boost adaptive capacity, food security, and contribute to climate change mitigation in resource-poor smallholder farming systems. As defined by the Food and Agriculture Organization (FAO), CSA refers to agriculture practices/technologies that sustainably increases productivity, resilience (adaptation), reduces/removes GHGs (mitigation), and enhances achievement of national food security and development goals (FAO, 2010). Thus, CSA is neither a new agricultural system nor a set of practice, but is a new approach, a way to guide the needed changes of agricultural systems, given the necessity to jointly address food security and climate change (Long *et al.,* 2016).

Farm households in Southern Highlands of Tanzania (Mbeya and Songwe Regions) have used CSA-practices on their farms voluntarily (Shetto *et al.,* 2007; Banjarnahor *et al.,* 2014; Mkonda and He, 2017). This study considered three CSA-practices which are crop rotation, crop residue retention and intercropping. Several studies have shown that crop rotation has the advantage of breaking pest's life cycle, deliver soil carbon sequestration, improve soil fertility through nitrogen fixation and suspend weeds hence increase crop productivity (Di Falco *et al.,* 2010). Usage of crop residue is another important aspect of CSA-practice as it can help increase soil moisture and reduce soil erosion while intercropping is potential in enhancing utilization of plant growth resources such as growing space, water, nutrients and light (Bybee-Finley and Ryan, 2018).

Previous researches mostly focus on the usage of single or a set of practices considered as a single unit. However, farmers typically use multiple practices to deal with their overlapping production constraints caused by climate change such as unreliable rainfall, rise in temperature, increased pest and diseases, soil erosion and low soil fertility. In addition, practice usage decisions are path dependent: the choice of practice used most recently by farmers is partly dependent on their earlier practice choices (i.e., Ghimire *et al.,* 2015;: Thuo et al., 2017; Nyasimi *et al.,* 2017; Kaweesa *et al.,* 2018; Aurangozeb, 2019). Interestingly, usage of multiple combinations of CSA-practices on households in Africa and Tanzania in particular has only recently received attention and empirical evidence is still scant particularly in Tanzania (Di Faclo *et al.,* 2013; Beyene *et al.,* 2017). This is to say, if the inter-relatedness of various CSA-practices are not considered, the effects of exogenous decision on usage of CSA-practices made by farming households which might underestimated or overestimated. Therefore, there is limited information on how usage of multiple CSA-practices by farming households in Tanzania responds to climate change. Then, to fill this gap of knowledge it is vital to examine the factors which motivate farming households to use different combinations of CSA-practices where a multinomial logit model was applied to jointly examine farming households' usage decisions.

Our study further adds to the literature on the economics of climate change adaptation in the following ways. First, we contribute to the limited literature on usage of multiple of CSA- practices in the face of changing climate conditions for better understand the synergistic effect of inter-related CSA-practices. To our knowledge, no similar empirical articulation of the relationship between social economics characteristics (household, plot, institutional characteristics) and alternative combinations of CSA-practices in the smallholder farming system has been done particularly in the Southern Highlands of Tanzania. Second, the study investigates for the first time, to our knowledge that treating farmers' usage choices in combination of practices, rather than as isolated decisions, is important in order to better understand the synergistic effect of interrelated climate smart agriculture practices. These are valuable contribution to help governments and development agencies design effective extension policies related farmers usage of CSA-practices.

Overview of Literature

The Concept of Climate-Smart Agriculture

The climate-smart agriculture (CSA) concept marked to guide agriculture management in the age of climate change (Anderson *et al.,* 2017). The aim of CSA is to support efforts at local and global level through using agricultural systems for sustainable achievement of food and nutrition security for all people at all times, through integrating necessary adaptation and capturing potential mitigation (Lipper *et al.,* 2014). The objectives used to achieve this aim are; sustainably increasing agricultural productivity to support equitable increases in incomes, food security and development; adapting and building resilience to climate change from the farm to national levels; and developing opportunities to reduce GHG emissions from agriculture compared with past trends (FAO, 2013). A practice is considered to be CSA based on its impact on these outcomes and agricultural interventions that meet these goals are considered "climate-smart" (ibid). Interventions ranging from climate information services to field management have potential to achieve these goals (Khatri-Chhetri *et al.,* 2016; Nyasimi *et al.,* 2017).

The usage of CSA-practices provides benefit to the farming household through increase productivity and household welfare. For example the study by Reppin *et al.* (2019) found that the usage of agroforestry system as a CSA-practice provides firewood for consumption and timber for income generation in Western Kenya. In Tanzania Kimaro *et al.* (2019) found that the usage of crop diversification by the farming households have shown a significant effect on the improvement of crop productivity and household food security measured by household dietary diversity score. Furthermore, Lin (2011) argued that the usage of crop rotation improve soil fertility, increases resilience and biodiversity on farm and controls pest and diseases. The study by Kimaro *et al.* (2019) also found the usage of conservation agriculture lead to increase maize production, improve adaptation to climate change, and mitigate greenhouse gases in Tanzania. The study by Asrat and Simane, (2017) in Ethiopia found that usage of CSA-practices by farming households between 2015 and 2017 increased farm level production by 22 percent. Generally, the usage of CSA-practices by farming households could lead to substantially improved food availability while reducing the impacts of climate change.

Conceptual Framework and Econometric Specification

According to Beyene *et al.* (2017) famers can either use agricultural practices in isolation or in a combination Teklewold *et al.* (2017) argued that farmers are faced with choices and trade-off when they use or decide to use new practice or practice. In developing countries farmers have different culture; different resource endowments and different preference hence have different decisions in practice usage (Loevinsohn *et al.,* 2013). Therefore, farmers can use a combination of practices in order to generate income, attain food security and reduce poverty. This implies that usage decision is inherently multivariate, and attempting univariate modelling would exclude useful economic information about interdependent and simultaneous usage decisions (Aryal *et al.,* 2018). When farmers face multiple innovations, they consider ways these different practices interact and take these interdependencies into account in their usage decisions. Ignoring these interdependencies can lead to inconsistent policy recommendations (Beyene *et al.* 2017).

Since the agricultural households are inherently exposed to the uncertainty of risk and shock events due to climate change, therefore effects of those uncontrollable factors play an important role in the usage of CSA-practices. Therefore, the theory of the maximization of expected utility was used in this study to explain the decisions of farming households on using CSA-practices in isolation or in combinations/ packages. This theory was elaborated by von Neumann and Morgenstern (1944) from the initial work of Bernoulli (1738) and has been the principle for decision-making theory. Based on this theory, farming households will use a given CSA-practice in isolation or in combination if the expected utility obtained from the practice exceeds that of the business as usual. Specifically, the farm household chooses the outcome that maximizes the utility gained from that choice. The utility derived from choice q for farm household equals

$$U_{iq} = \mu_{iq} + \varepsilon_{iq} \quad \text{...(1)}$$

Where U_{iq} is the average utility associated with choice q for household i, and ε_{iq} is the random error associated with that choice. The probability of choosing alternative 1 is the probability that the utility from alternative 1 exceeds the utility from alternative 2:

$$\Pr(y_i = 1) = \Pr(U_{i1} > U_{i2}$$
$$= \Pr(\mu_{i1} + \varepsilon_{i1} > \mu_{i2} + \varepsilon_{i2}$$
$$= \Pr(\varepsilon_{i1} - \varepsilon_{i2} > \mu_{i2} - \mu_{i1} \quad \text{............................(2)}$$

When there are J choices, as in our case, the probability of choice y is

$$\Pr(y_i = q) = \Pr(U_q > U_j \forall j \neq q) \quad \text{..................(3)}$$

The specific form of the discrete choice model is determined by the assumed distribution of ε and the relationship of how U_q, the average utility for choice q, to measured variables. To obtain the Multinomial Logit (MNL) model, let the average utility be a linear combination of the attributes of household, plot, and institutional:

$$\mu_{iq} = Z_i \vartheta_q \quad \text{..(4)}$$

Where Z is a *axk* matrix of the explanatory variables, and ϑ is a *kx1* vector of parameters to be estimated. Equation 4 serves as a basis for the maximum likelihood estimator. Let $Pr(Y_i=q \mid Z_i, \vartheta_2, \ldots \ldots \ldots \vartheta_j)$ be the probability of observing $Y_i=q$ given Z_i with parameters ϑ_2 through ϑ_j. Let p_i be the probability of observing the value of y that was actually observed for the *ith* observation. Therefore, the likelihood function, if the observations are independent, is:

$$L(\vartheta_2, \ldots\ldots\ldots, \vartheta_j \mid Y, Z) = \prod_{i=1}^{N} p_i \quad \text{.................(5)}$$

Substituting p_i in the above equation yields:

$$(\vartheta_2, \ldots\ldots\ldots, \vartheta_j \mid Y, Z) = \prod_{i=1}^{N} \coprod_{yi=q} \frac{\exp(Z_i \vartheta_q)}{\Sigma_{j=1}^{j} \exp(Z_i \vartheta_q)} \quad \text{....(6)}$$

Taking logs, we obtain the log likelihood equation which can be maximized with numerical methods to estimate the ϑ's. The resulting estimates are consistent, asymptotically normal, and asymptotically efficient (Amemiya, 1981).

Empirical Review

A number of studies have been conducted on determinants of usage of climate smart agriculture practices. For example, using binary a study conducted by Aurangozeb (2019) in Rangpur, India, showed that practices usage of rural women had significant negative correlation with their usage of integrated homestead farming practices. According to Thuo *et al.* (2017), socioeconomic factors like access to the market, gender, education, availability of extension services, land size, subsidy policy, and income level were all found to be positive and significant factors in determining usage of tissue culture practice in the Lower Eastern region of Kenya. A study conducted by Mwangi and Kariuki (2015) which slightly deviated from previous studies concluded that, a key precondition for usage to occur is the perception of farmers.

The study of Ghimire *et al.* (2015) revealed that the factors affecting the probability of usage are seed access, yield potential, consumers' acceptability of rice varieties, extension service, farm size, and education. Socio-economic characteristics of farmers such as level of education, farm size, and age were identified as major factors affecting the usage of practice (Mittal and Mehar 2015). Manda *et.al.* (2015) found that the propensity to use decreased with access to off-farm income, gender of the household head and distance to input and output markets. The study contradict with the previous studies by researchers such as Lavison (2013) who concluded that gender of a farmer, income generated from improved practice and market availability to the farmers had all influenced the usage of agricultural practice. Likewise, Kariyasa and Dewi (2013) also revealed that information sources, level of education, distance to the meeting place, the level of productivity and age influenced the usage of Integrated Crop Management Farmer Field School (ICM-FFS) positively and significantly.

Fisher *et al.* (2015) applied a multinomial logit model to examine the usage of different varieties of maize in eastern and southern Africa. The study found that compared with younger heads, older household heads were more likely to grow local maize and less likely to grow non-DT modern maize, probably reflecting reduced willingness of older farmers to give up familiar production practices. Households headed by a more educated individual were more likely to grow DT maize and less likely to grow local maize, suggesting educated individuals process information about new practices more quickly and effectively (Foster and Rosenzweig 2010).

The study by Nkonya *et al* (1997) found that the farming experience of the household head was the only factor that significantly influenced usage of improved maize in the northern zone of Tanzania. In addition, the study found that the number of livestock owned by the household positively and significantly influenced the usage of chemical fertilizers. The study found no household characteristics such as age, sex, education and household size that influenced the intensity of fertilizer usage.

Study by Eleni (2008) showed that farmers who engaged in off farm activities were less involved in the continued use of soil and water conservation practices as a CSA-practice. Similarly, the findings by Belay *et al.* (2004) indicated that involvement in off farm activities negatively influenced the continued use of soil and water conservation measures. Eleni (2008) also showed that farmers who invest more in fertilizers are more involved in the continued use of Soil and water conservation measures.

Methodology

Study area

The study was conducted in two regions and four districts. That is, in Mbeya and Mbarali districts in Mbeya Region and Mbozi and Momba districts in Songwe Region in Tanzania. These regions are in the Southern Highlands, which is the breadbasket area of Tanzania where a variety of food crops are cultivated such as maize, beans, soya beans and paddy rice. The study area was selected based on the presence of major food crops such as maize, paddy rice, beans and soya beans. In addition, food and nutritional security vulnerability was another selection criterion, because 37 percent of children under five years are stunted (TFNC, 2014), and there is absence of integrated interventions in recent years. The study area is also considered as appropriate for this study because farmers primarily rely on food crop production for their livelihoods. Furthermore, mixed agronomic practices were also the main driver for selection of the study area.

Sampling and data collection

This study uses cross-sectional household data collected through structured interviews under the project titled ‘‘Integrated Project to Increase Agriculture Productivity in the Bread Basket Area of Southern Highlands of Tanzania”. The objective of the project was to stimulate agricultural development and food increase food security by increasing the productivity of selected commodities -maize, rice, soya beans and common beans. This was achieved through a value chain development approach, integrating various areas of intervention, such as development of farmer organizations, improved access to inputs through agro-dealer networks, extension, establishment of CSA-practices demonstration plots and access to output markets through contracting with processors. Four districts (Mbarali, Mbozi, Momba and Mbeya) from Mbeya and Songwe regions were included in gathering the data. The study population composed of farming households cultivating food crops (paddy, maize, common beans and soya beans). Since this was a household level, the selected participants for the survey were households. Simple random sampling technique was used to select farmer organizations from lists obtained from the district agriculture irrigation and cooperative offices. Within selected farmers' organizations, households were randomly chosen from households' lists provided by the group leaders using simple random sampling techniques. characteristics, crop production and marketing, climate smart agriculture practices used, input use, food consumption, food insecurity coping strategies, and other farm- and farmer-specific characteristics.

Empirical Model

The CSA-practices considered in this study include crop rotation, crop residue and intercropping, providing eight mutually exclusive combinations of practices (2^3). Based on the discussion so far, an MNL model is used to estimate the probability of CSA-practices usage conditional on a vector of explanatory variables. Household characteristics are classified among eight combinations of CSA-practices based on the usage status as shown in Table 1.

Table 1: Combination of usage of crop rotation, crop residue and intercropping

SN	CSA combinations	Description
1	C0R0I0	C0R0I0 = 1 if a farmer is a non-user
2	C1R0I0	C1R0I0 = 1 if a farmer only uses crop rotation; 0 other wise
3	C0R1I0	C0R1I0 = 1 If a farmer uses crop residue; 0 other wise
4	C0R0I1	C0R0I1 = 1 If a farmer uses intercropping; 0 other wise
5	C1R1I0	C1R1I0 = 1 If a farmer uses crop rotation and crop residue; 0 other wise
6	C1R0I1	C1R0I1= 1 If a farmer uses crop rotation and intercropping; 0 other wise
7	C0R1I1	C0R1I1= 1 If a farmer uses crop residue and intercropping; 0 other wise
8	C1R1I1	F1P1I1= 1 If a farmer uses crop rotation crop residue and intercropping; 0 other wise

Total sample sizes of 1557 households were then selected for the survey. However, some households (114) were dropped during data cleaning prior to analysis as they did not have sufficient data thereby, reducing the sample to 1443 households. Data collection for this study was done in February 2017 through face-to-face administration of questionnaires. We used tablets for data collection under the android application called Open Data Kit (ODK) in which the questionnaire was in both Swahili and English versions. Questionnaires were completed using tablet-based application (Open Data Kit). The survey collected information on household demographics, socioeconomic

Let Y_j takes the value 1 if the J^{th} household chooses the q^{th} combination of CSA-practice; 0 otherwise. The relative odds (P) of CSA-practice choices are expressed using the following MNL model:

$$\log \frac{p_{jq}}{p_{jm}} = Z_j^{'}\theta_q + \varepsilon_j,$$
$$j = (1,\ldots\ldots,n), q = (1,\ldots\ldots,\mathrm{M}-1) \qquad \ldots\ldots(9)$$

Where, log is the natural logarithm, Z is an exogenous explanatory vector, θ is a vector of parameters to be estimated, and is a random disturbance term. The conditional probability for the choice is derived as in the following [for more detail, see Greene (2002)

$$p_{jq} = prob(Y_{jp} = 1) = \frac{\exp(Z'_{ji}\theta_q}{\Sigma_{R=1}^{M} \exp(Z'_{ji}\theta_q},$$
$$q = (1, \ldots\ldots, M-1) \qquad \ldots(10)$$

Which, alternatively, can be written as:

$$p_{jq} = \frac{\exp(Z'_{j}\theta_q}{\Sigma_{R=1}^{M-1} \exp(Z'_{j}\theta_q}, q = (1, \ldots\ldots, M-1) \ldots.(11)$$

$$p_{jq} = \frac{1}{\Sigma_{R=1}^{M-1} \exp(Z'_{j}\theta_q}, q = (1, \ldots\ldots, M-1) \ldots(12)$$

Variables used in the empirical analysis
Dependent variables

The study considered the dependent variables (CSA-practices) as a combination of crop rotation, crop residue retention and intercropping as shown in Table 1. According to Teklewold *et al.* (2019) crop rotation is defined a strategy for growing more than one crop across time. As a CSA-practice crop rotation play an important role for adaptation to climate change as it helps in improving soil fertility, decreasing the incidence pests and diseases, Improves on-farm diversification and prevent soils erosion (Teixeira *et al.,* 2018; Ma *et al.,* 2018). In terms of mitigation to greenhouse gases crop rotation reduces the need for nitrogen fertilizers application when leguminous introduced and maintain and or improves soil carbon stock (Teklewold *et al.,* (2019). The practice is important in the Improvements in farm productivity of pasture, feed and food crops (Teixeira *et al.,* 2018).

Intercropping is defined as growing of two or more crops per unit of land area simultaneously (Dyer *et al.,* 2012). The practice is considered climate change adaptation strategy as it control weeds, improve water holding capacity, it improve physical, chemical and biological characteristics of the soil (Bybee-Finley and Ryan, 2018). Above all it contributes to reduce crop failure risk due to weather shock hence increases in food availability and dietary diversity (Teklewold *et al.,* 2019). In mitigation of greenhouse gases intercropping maintain or improves soil carbon stock or organic matter content and reduces the need for chemical fertilizer (Hassen *et al.,* 2017). According to Teklewold *et al.* (2019) the practice improves productivity hence promoting sustainable utilization of resources such as land and water. Crop residue retention is considered to be crop remains which are left in the field after harvest (Bolinder *et al.,* 2020). Crop residue retention enhances soil moisture, fertility and reduces soil erosion (Ma *et al.,* 2018; Chalise *et al.,* 2019) In addition, the practice increases carbon storage in soils, reduces use of synthetic fertilizers and crop yields and income (Bolinder *et al.,* 2020 ; Bolinder *et al.,* 2020).

Explanatory variables

The explanatory variables included in the analysis are based on the empirical literature (Kaliba *et al.* 2000; Kassie *et al.,* 2013; Kassie *et al.,* 2014; Manda *et al.,* 2015; Beyene *et al.* 2017; Teklewold, *et al.* 2017). Education, (measured by the years of schooling) was expected to be positively and significantly associated with usage of CSA-practices. According to Khonje *et al.* (2015) educated farm household head is expected to use CSA-practices individually or in combination than households with less or no education. In most cases, usage of CSA-practices can be a strategy that is part of an overall household strategy to improve livelihood and thus, the literacy status of the household head's spouse may also affect it. Hence, the study hypothesized a positive relationship between education and usage of CSA-practices either in isolation or in combination.

Age, measured in years, was expected to increase or decrease the probability of using CSA-practices. This implies that as a household head become aged he/she become more/less averse to risk regarding agricultural practices (Kaliba *et al.,* 2000). The gender of the household head measured as a dummy variable, was expected to influence farming households to use different combinations of CSA-practices. According to Kaliba *et al.* (2000) social behaviour makes male informants to address male-headed households leaving female-headed counterparts uninformed. A study by Doss and Morris (2001) found that female headed households are less likely to use agricultural practices because of limited access to resources such as agricultural extension service, land acquisition and education. It is, therefore, hypothesised that expected usage of CSA-practices in male headed households to be greater than those of the female headed households.

Household size measured in number was used as a proxy for available labour in the household. Large households are expected to use CSA-practices than smaller households. This is due to the fact that the usage of CSA practices requires additional labour. Farming household' decision to use a CSA-practice will be dependent on the labour force available. For example, the larger household could be associated with a greater labor force being available to the household for the timely operation of farm activities. Farm plot characteristics such as total plot size, land ownership, soil fertility, and distance to plot from homestead may influence farming household' decisions to use CSA-practice and thus, the study need to control for these factors (Beyene *et al.,* 2017). For example, distant plots not only cost more to transport inputs but are also difficult to monitor. Therefore, farmers may be less interested in using a certain CSA-practice in distant plots. In the Southern Highlands of Tanzania particularly Mbeya and Songwe regions, land fragmentation is very high, and farmers operate multiple small plots. The small plot size measured in acre can motivate farming households to use a certain CSA-practice which require less investment like crop rotation, crop residue retention and intercropping.

Variables included in the model to capture institutional factors that affect CSA-practices were access to extension services, farmer organization memberships and access to demonstration plots. Access to extension services measured as a dummy variable is an important source of technical information for farmers. It is, therefore, posited that access to extension services will increase usage of CSA-practices either in isolation or in combination. Access to agricultural extension services typically plays a crucial role in enhancing usage and innovation (Chowdhury *et al.,* 2014). Farmer organization membership measured by dummy variable (membership in more than one farmer organization =1 or otherwise) may increase access to information on CSA- practices hence increase the probability of using CSA-practices either in isolation or in combination (Olwande and Mathenge 2012). Access to agricultural demonstration plots measured by dummy variable increased knowledge about the CSA-practices. Farming households which are knowledgeable about the CSA-practices are more likely to have higher usage than those which do not know about the practices (Zhang *et al.* 2002).

According Kassie *et al.* (2013) plot size measured in acre can influence the usage of agricultural practices. For example, farming households with larger plots can decide to allocate more land to practices such as the combined CSA-practices. This means that farming households with larger farm would be more inclined to the usage CSA-practices compared with those with less land. However, farming households with larger plots might use less intensive methods than those with small plots (ibid). Therefore this study hypothesises that farming households with larger plots will be more likely to use the CSA-practices either in isolation or in combination compared to farming households with smaller plots. Other variables used in this study are shown in Table 2.

Results

Multinomial Logit Regression Model Results and Discussions

Before running the model, different tests which are very essential for multinomial logit model were undertaken. The Multinomial logit model was employed to determine the factors that influence farming households to choose a combination/package of climate smart agriculture practices in the study area. The model was tested for the validity of the independence of the irrelevant alternatives (IIA) assumptions, using the Hausman test for IIA. The test failed to reject the null hypothesis of the independence of the usage of CSA-practices, suggesting that the multinomial logit specification is appropriate to model usage of CSA-practices. The model was fitted into STATA version 13 and tested for both heteroskedasticity and multicollinearity.

Table 2: Definition of variables in the research model

Variable	Type of variable	Description of the variables
Household size	Discrete	Number of people living together under the same roof and eating from the same pot
Education of the household head	Discrete	Number of years spent in schooling
Gender of the household head	Dummy	1 if the head is male, 0 otherwise
Age of the household head	Continuous	Age of household head (in years)
Marital status of the household head	Dummy	1 if the head is male, 0 otherwise
Farming experience of the household head	Continuous	Household head’s farm experience in years
Livestock ownership (TLU)	Continuous	Livestock holding in tropical livestock units
Mobile phone ownership	Dummy	1 if the head is male, 0 otherwise
Radio ownership	Dummy	1 if the head is male, 0 otherwise
Television ownership	Dummy	1 if the head is male, 0 otherwise
Ownership of productive assets	Discrete	Productive assets owned
Income diversification	Continuous	Number of different income sources
Land ownership	Dummy	1 if the head is male, 0 otherwise
Access to demonstration plots	Dummy	1 if the head is male, 0 otherwise
Access to extension services	Dummy	1 if the head is male, 0 otherwise
Distance to the extension office	Continuous	Distance from all-weather roads in minute
Access to tarmac road	Continuous	Distance from all-weather roads in minute
Membership of multiple organizations	Dummy	1 if the head is a member of more than one organization male, 0 otherwise
Access to loan	Dummy	1 if the head is male, 0 otherwise
Average plot distance	Continuous	Distance from all-weather roads in minute
Plots cultivated	Discrete	Number of plots cultivated
Soil fertility	Dummy	1 if the head is male, 0 otherwise
Soil erosion	Dummy	1 if the head is male, 0 otherwise
Production Diversity	Discrete	Number of crops cultivated in acre
Total Plot Size	Discrete	Total plot size own in acre
Mbozi District	Dummy	1 if the head is male, 0 otherwise
Momba District	Dummy	1 if the head is male, 0 otherwise
Mbarali District	Dummy	1 if the head is male, 0 otherwise

Preliminary diagnostics of the variables to be used in the econometric analysis

Preliminary diagnostics for statistical problems of multicollinearity and heteroskedasticity were conducted to the variables for socio-economic, institutional and climate related incidences. According to Wooldridge, (2010) multicollinearity exists whenever two or more of the predictors in a regression model are moderately or highly correlated. This problem was tested using variance inflation factor (VIF) for all continuous variables. The results confirmed that there was no serious linear relationship among the explanatory continuous variables tested since VIF values were less than 10. Similarly, results confirmed that there was no serious linear relationship among the categorical explanatory variables because contingent coefficients were less than 0.75 in all cases. By rule of thumb, there was no strong association among all hypothesized explanatory variables. Therefore, all of the proposed potential explanatory variables were used in regression analysis.

To detect heteroskedasticity for all hypothesized explanatory variables, the white test was used. Unlike the Breusch-Pagan test which would only detect linear forms of heteroskedasticity, the white test was preferably applied as it incorporates both the magnitude as well as the direction of the change for non-linear forms of heteroskedasticity (Wooldridge, 2010). White's general test is a special case of the Breusch-Pagan test, where the assumption of normally distributed errors has been relaxed. The results indicated the absence of heteroskedasticity as a chi^2 of 118 was insignificant. Therefore, the use of the MNL model description was found to be suitable, and model has been used previously by different scholars (Deressa, *et al.,* 2008) to estimate the decision for the usage of climate change adaptation technologies by farmers.

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Determinants of using Combination of CSA-practices

A multinomial logit (MNL) regression model was used to empirically identify drivers for farmers' usage of multiple combinations of CSA-practices. In this study, an unordered multinomial logit model is useful because it can take care of categorical dependent variables (such as nominal categories of dependent variables having multiple choices). The model estimates the effect of the individual variables on the probability of choosing a type of multiple combination CSA- practices. CSA-practices used in the study areas were characterized after which the most common practices used by farmers (or decision categories) were identified using principle component analysis (PCA). Principal Component Analysis (PCA) was used to group these practices whereby related practices were grouped into the cluster (components) based on use. The PCA is superior compared to the conventional grouping method which would make it difficult to conclude about a group in cases where few practices could represent the entire group. The components were rotated using the varimax method so that a smaller number of highly correlated CSA-practices would be put under each component for easy interpretation and generalization about a group (Chatterjee *et al.,* 2015). These practices comprised of the decision categories for the multinomial logit model having combinations as shown in Table 3.

The hypothesized explanatory variables were entered into Multinomial logit model (MNL) to see their individual and combined effects on the usage of CSA-practices. The results indicate the probability of chi-square where likelihood ratio statistics are highly significant at $p<0.0000$, suggesting that the model has a strong explanatory power. The parameter estimates of the MNL model was used to provide the direction of the effect of the independent variables on the response variable, where parameter estimates represent neither the actual magnitude of change nor the probabilities. As mention earlier, the parameter estimates of the MNL model provide only the direction of the effect of the explanatory variables on the response variable: parameter estimates do not denote actual magnitude of change or probabilities. Thus, the marginal effects from the MNL, which measure the expected change in probability of a particular choice of CSA-practices being made with respect to a unit change in an independent variable, are indicated and discussed. The marginal effect results were considered for interpretation. Table 5 provides an overview of the key drivers of multiple CSA usage to ease interpretation highlighting only the variables that are significant for three or more CSA options and the positive or negative association.

Table 5 Marginal effects from the multinomial logit for the choice of CSA-practices

Variables	C1R0I0	C0R1I0	C0R0I1	C1R1I0	C1R0I1	C0R1I1	C1R1I1
	dy/dx	dy/dx	dy/dx	dy/dx	dy/dx	dy/dx	dy/dx
Household Characteristics							
Household size	-0.0003	-0.00683	0.0034	0.0003	0.0034	0.0006	-0.0030
	0.803	0.0210**	0.1310	0.8910	0.1030	0.8980	0.6040
Education of the household head	0.0004	-0.00006	-0.0019	-0.0048	-0.0002	0.0016	0.0088
	0.554	0.9750	0.3210	0.0380**	0.9140	0.6650	0.0650*
Gender of the household head	0.0041	-0.00938	-0.0545	0.0073	-0.0372	-0.0035	0.1297
	0.69	0.7210	0.0040***	0.7980	0.0580*	0.9360	0.0360**
Age of the household head	0.0001	-0.00014	-0.0008	0.0003	-0.0007	0.0003	0.0000
	0.651	0.7890	0.0770*	0.4880	0.1130	0.7930	0.9890
Marital status of the household head	-0.0128	0.01386	0.0152	0.0049	0.0345	0.0141	-0.0923
	0.133	0.5830	0.3090	0.8250	0.0690*	0.7190	0.1030
Farming experience of the household head	-0.0002	-0.00011	0.0002	-0.0010	0.0006	0.0027	-0.0009
	0.19	0.8330	0.5580	0.0610*	0.1700	0.0050***	0.4800
Households resource endowment							
Livestock ownership (TLU)	0.0005	-0.00071	-0.0057	-0.0002	0.0012	0.0002	0.0041
	0.337	0.7190	0.0960*	0.9070	0.2910	0.9430	0.3860
Mobile phone ownership	0.0018	-0.00648	-0.0137	0.0324	-0.0051	-0.0067	-0.0194
	0.752	0.6480	0.2910	0.1220	0.7140	0.8180	0.6320
Radio ownership	0.0081	-0.00270	-0.0004	0.0030	0.0068	0.0094	-0.0140
	0.155	0.8110	0.9650	0.7970	0.5350	0.6410	0.5940
Television ownership	-0.0120	-0.00009	-0.0184	0.0042	-0.0009	0.0119	-0.0237
	0.16	0.9960	0.1950	0.7630	0.9390	0.6680	0.4980
Ownership of productive assets	-0.0004	-0.00042	0.0067	-0.0046	-0.0080	0.0050	0.0127
	0.895	0.9450	0.2090	0.4260	0.1600	0.6230	0.3510

**** $p<0.01$, ** $p<0.05$, * $p<0.1$ significance level*

Table 5: Continue

Variables	C1R0I0	C0R1I0	C0R0I1	C1R1I0	C1R0I1	C0R1I1	C1R1I1
	dy/dx	dy/dx	dy/dx	dy/dx	dy/dx	dy/dx	dy/dx
Income diversification	-0.0078	-0.02949	-0.0302	-0.0112	-0.0100	-0.0218	0.1476
	0.045**	0.0010***	0.0000***	0.1850	0.0990*	0.1810	0.0000***
Land ownership	0.0036	0.00475	-0.0035	-0.0139	-0.0150	-0.0064	0.0281
	0.456	0.7640	0.7270	0.3860	0.1420	0.8080	0.4030
Institutional services							
Access to demonstration plots	-0.0052	-0.0045	0.0075	-0.0062	-0.0169	-0.0206	0.0601
	0.286	0.6970	0.4390	0.5500	0.0730*	0.278	0.0150**
Access to extension services	-0.0014	0.01345	0.0176	0.0154	0.0256	0.0344	-0.0546
	0.865	0.2970	0.2300	0.1640	0.0300**	0.1710	0.1070
Distance to the extension office	-0.0002	-0.00019	0.0000	0.0001	0.0002	-0.0007	0.0006
	0.064*	0.4240	0.9450	0.4450	0.0860*	0.1060	0.1890
Access to tarmac road	0.0000	-0.00004	0.0000	0.0000	0.0001	-0.0001	-0.0002
	0.09*	0.6290	0.9140	0.4550	0.0550*	0.7740	0.4460
Membership of multiple organizations	-0.0007	-0.02651	-0.0413	-0.0131	-0.0065	-0.0622	0.1384
	0.897	0.0710*	0.0190**	0.2790	0.5880	0.0080***	0.0000***
Access to loan	0.0061	-0.00504	-0.0088	-0.0007	-0.0089	-0.0033	0.0437
	0.235	0.7520	0.4360	0.9580	0.4190	0.8940	0.1680
Plot Characteristics							
Average plot distance	0.0002	-0.00006	-0.0001	0.0000	-0.0002	0.0007	-0.0009
	0.039**	0.8160	0.8060	0.9990	0.4720	0.1970	0.2040
Number of plots cultivated	-0.0009	-0.00021	-0.0042	-0.0002	-0.0019	-0.0202	0.0516
	0.638	0.9570	0.4790	0.9700	0.6870	0.0380**	0.0000***
Soil fertility	0.0056	-0.00335	-0.0039	-0.0023	-0.0109	0.0148	-0.0219
	0.169	0.7410	0.6830	0.8310	0.2530	0.4260	0.3620

**** $p<0.01$, ** $p<0.05$, * $p<0.1$ significance level*

Table 5: Continue

Soil erosion	0.0105	-0.00975	-0.0033	0.0063	0.0311	0.0315	-0.0500
	0.051*	0.4100	0.7770	0.5800	0.0010***	0.1010	0.0640*
Production Diversity	-0.0306	-0.02439	0.0226	0.0125	0.0313	0.0787	0.0018
	0.26	0.3670	0.3500	0.6160	0.2320	0.0940*	0.9770
Total Plot Size	0.0003	-0.00013	-0.0015	0.0010	0.0007	-0.0008	0.0003
	0.182	0.8190	0.1860	0.0030**	0.4260	0.6200	0.8790
Geographical Location							
Mbozi District	-0.0875	0.02047	-0.0212	0.0391	-0.0424	0.0584	0.0809
	0.001***	0.1210	0.2000	0.0270**	0.1700	0.0220**	0.0450**
Momba District	-0.0806	0.00072	-0.0562	0.0695	0.0135	-0.1347	0.2496
	0.001	0.9700	0.1040	0.0000***	0.4820	0.0010***	0.0000***
Mbarali District	0.0145**	-0.00653	0.0147	-0.0200	0.0638	-0.0262	-0.0790

**** $p<0.01$, ** $p<0.05$, * $p<0.1$ significance level*

Household size had a significant and negative influence on the usage of crop residue only (C0R1I0). This implies a marginal increase in household size would lead to decrease in the probability of using crop residue as a CSA-practice by 0.683 percent. This finding is contrary to Lugandu (2013) in Karatu and Kongwa districts of Tanzania who found that the household size influenced usage of conservation agriculture with non-user having relatively smaller family size implying that the source of labour for the smaller household sizes is limited hence impacting on usage of conservation agriculture. This different is due to the fact that farming households in the study area who own livestock likely depend on their residues as fodder and are therefore less inclined to retain the residues on the fields.

Gender of the household head is significantly and negatively connected with the likelihood of using intercropping (C0R0I1) by 0.004 at 1% level of significance. The findings shows that female headed households were 5.45 percent associated with the usage of intercropping in isolation as compared to male headed households. Result shows that there is a negative association of gender with the likelihood of using combination of crop rotation and intercropping in combination (C1R0I1) at 0.0580 probability level. In addition, gender of the household head is significantly and negatively connected with the likelihood of using combination of crop rotation, crop residue and intercropping (C1R1I1) by 0.0360 at 5% level of significance. The findings show that female-headed households were 12.97 percent associated with the usage of combination of crop rotation, crop residue and intercropping as compared to male headed households. These findings concur with the argument that female have more likelihood of using these practices than the male because female are more engaged in agriculture activities than male, regardless they have less control of production resources (Obayelu *et al,* 2014).

As expected, education level of the household head is significantly and positively connected with the likelihood of using combination of crop rotation, crop residue and intercropping (C1R1I1) by 0.0650 at 10% level of significance. The findings show that the education level of the household headwas0.88 percent associated with the usage of combination of crop rotation, crop residue and intercropping. Contrary to expectation, the level of education of the household head decreases the probability of using a combination of crop rotation and crop residue (C1R1I0) at 5 percent probability level ($p<0.0380$). This implied that a unit increase in the level of education would result in a 0.48 percent decrease in the probability of using a combination of crop rotation and crop residue. It could be that educated household did not use these combinations of practices because it does not offer risk reduction measures which could safeguard their investment against prevailing risks of climate change. These results are in agreement with the study of Aryal *et al.,* (2018) which found the level of education to be significant and negatively correlated with the usage of mixed farming at $p<0.001$ level of significant. Gido *et al.* (2015) argue that higher levels of education tend to build the innovativeness and ability to assess risks by farmers for proper farm adjustments.

As expected, experienced farmers in farming have an increased likelihood of using a combination of crop residue and intercropping (C0R1I1) as CSA-practice. The farming experience of the head of the household had significant and positive connection with the usage of a combination of crop residue and intercropping (C0R1I1) at 1% significant level ($p<0.0050$). Farming households with high experience in farming have more skills in climate smart agriculture and are in the position to spread climate change threat by using CSA-practices complementarities such as practising combination crop residue and intercropping (C0R1I1). The results of this study reveal that as farming households advance in years of farming experience, it increases the usage of combination of crop residual and intercropping by 0.27 percent as a CSA-practice. Consistent with this study, Ngwira (2014) found that household with high experience in faming activities used conservation agriculture practices than households with less experience.

Crop diversification as measured by the number of crop cultivated was found to have a positive and significantly influence on usage of combination of crop residue and intercropping (C0R1I1) This implies that farming households with higher crop diversification are more likely to use a combination of crop residue and intercropping. Therefore, they have to use different combination of CSA-practices for the assurance of higher yield from each crop cultivated. Access to tarmacked road measured by working distance to the tarmacked roads in minute had a positive influence on the probability of using a combination of crop rotation and intercropping (C1R0I1) at less than 1% significant level ($p<0.000$) as CSA-practices. This implies that a marginal increase in access to tarmacked roads would lead to increase in the probability of using a combination of crop residue and intercropping by 0.01 percent. It is also positively and significant for the farming households which use crop rotation in isolation (C1R0I0). The positive sign implies that farming households with access to tarmacked road invest more on CSA-practices as they have assurance of the access to inputs and output markets.

Results of the multinomial logit models shows that access to extension services has positive and significant association with the probability of using a combination of crop rotation and intercropping (C1R0I1) at $p<0.0300$ level of significance. This indicates that a one-unit increase in the extension contact is likely to increase the likelihood of farming household using a combination of crop rotation and intercropping as CSA-practices by 2.56 percent. This implies that farming households with regular access to extension services are more likely to be informed on CSA-practices. The result is consistent with a study by Mmbando and Baiyegunhi (2016) who found positive relationship between extension services and usage of improved maize varieties in Hai district in Kilimanjaro Tanzania. In addition, the study found that farming households which are away from the office of the extension officer are less likely to use crop rotation in isolation. This is plausible because long distance to the extension office for extension services increases transaction costs. The result is consistent with a study by Aryal *et al.,* (2018) who found that farmers who stay away from the office of the agricultural extension office were less likely to use CSA-practices in the Indo-Gangetic Plains of India.

Livestock ownership measured by Tropical

Livestock Unit has negative and significant association with the probability of using intercropping in isolation (C0R0I1) at p<0.0960 level of significance. This indicates that a one-unit increase in the tropical livestock unit is likely to decrease the likelihood of farming household use of intercropping by 0.57 percent. This implies that there is a decrease in the usage of intercropping as the livestock size increases. This might be because as the livestock increases, farming households have no time to engage on crop production compared to farming households with fewer livestock. On contrary, Tesfaye (2008) reported that the number of livestock owned had a significant and positive influence on usage of fertilizer in Ethiopia.

Larger farm sizes are more likely to use a combination of crop rotation and crop residue retention. This indicates that a one-unit increase in the size of the farm is likely to increase the likelihood of farming households to use a combination of crop rotation and crop residue by 0.10 percent. Probably, this has been the situation because most of these farming households in the study area follow the legume-cereal cropping system.

Conclusions

Developing countries in Sub-Saharan Africa face challenges in agriculture development due to change in market conditions, food demand and climate. Climate change causes a major threat to agricultural production and food security in Tanzania, and climate-smart agriculture is crucial in addressing the potential impacts. CSA-practices can increase crop productivity, income mitigate the greenhouse gases hence improve food security. Whereas previous research mostly focused on the usage of single CSA-practices, usage of multiple combinations of CSA-practices on households in Africa has recently received attention, even though empirical evidence is still scant. In this paper, we have identified the determinants of usage of multiple combinations of CSA-practices using multinomial logit.

The results show that usage of CSA-practices is primarily influenced by number of factors, including household, plot and institutional characteristics. Nevertheless, there is scope for promoting greater complementarities among these CSA-practices. The study found that the major determinants of farming households' decisions to use combination of CSA-practices are the household size, production diversity, farm size, access to extension services, livestock ownership and occupation. Analysis of determinants of usage revealed that crop diversification, gender and livestock ownership had a positive and significant influence on the usage of combination of crop residue and intercropping (C0R1I1). In addition, education level and gender of the household head positively and significantly influenced the usage of combination of crop rotation, crop residue and intercropping (C1R1I1).

Based on the above results, it is important to focus on policies and plans that promote each CSA-practice as a combination including other inter-related practices could contribute to upscale CSA-practices usage while harnessing the synergies between them. Dissemination of CSA-practices knowledge and its role in climate risk mitigation is critical to promote it. More CSA training for farmers, government extension staff working at the local level, and use of communication tools to share and promote knowledge on CSA-practices use to combat the global challenge of climate change are essential. Understanding barriers and enabling conditions to CSA-practices usage helps in designing and formulating extension messages and agricultural policies that can accelerate CSA-practices dissemination and help safeguard agricultural production and food security in Tanzania. In addition, agricultural policy makers should focus at enhancing smallholder farmers' household characteristics by reviewing farmer extension so as to come up with a package that is tailored to the perceived actual needs of farming households and designing farm management usage programmes based on the farmers household characteristic, such as education, gender, livestock ownership and membership to social groups.

However, it is important to notice that even though the study estimated the determinants of multiple combination of CSA-practice but the study did not consider the implication for the usage to household welfare. Therefore, other research should go further to investigate whether the usage of combination of CSA-practices has higher and positive welfare and productivity effects in the face of climate change.

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