Welfare Effects of Farming Household' Usage of Combination of Climate Smart Agriculture Practises in the Southern Highlands of Tanzania.

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Abstract

Climate change is a growing challenge to food security, especially for the developing countries which depend on agriculture for their livelihood. Climate Smart Agriculture (CSA) is the approach proposed by the Food and Agriculture Organization (FAO) to improve agricultural productivity and income, climate change adaptation capacity and mitigation of greenhouse gases hence improving food security. Despite the promotion of CSA-practices in Tanzania, its impact on household food security is not well documented. The study used a Multinomial Endogenous Switching Regression Model (MESR) to evaluate the impact of CSA-practises on food security in Mbeya and Songwe regions in Tanzania. Multistage sampling was conducted in which a total of 1443 farming households were interviewed. The study found that the usage of CSA-practises can increase or decrease Food Variety Score per adult equivalent unit when used either in isolation or in combination. Intercropping has the best payoff among the CSA-practices considered in this study. A combination of crop rotation and residue retention and a combination of crop rotation, intercropping and residue retention showed a positive impact on Food Variety Score per adult equivalent unit but lower magnitude compared with practises used in isolation. The study found that the usage of all three CSA-practices does not necessarily result in better returns compared to other practices. The study recommended that regardless of unobserved and observed effects, using crop rotation, residue retention and intercropping in isolation results into the highest food variety score per adult equivalent among all possible combinations.

Keywords: Climate Change; CSA- practises; Food Security; Counterfactual Analysis; Tanzania

JEL Classification Codes: Q18, Q54

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1.0 Background Information

Climate change is a growing challenge to food security especially for the developing countries which depend on agriculture for their livelihood (FAO, 2019; FAO, 2017). To meet food demand by 2050, the world's agricultural system must produce more food for a growing population and provide economic opportunities for rural dwellers whose economy depends on agriculture (Harvey *et al*., 2018). Despite a reasonable food crop production worldwide, in 2018, 821 million people in the world were estimated to be food insecure, an increase up from 815 million in 2017 (FAO, 2019). In sub-Saharan countries (SSA) food insecure people increased from 181 million in 2010 to 236 million in 2017 (FAO, 2018). This reflects that the region is highly affected by food insecurity which is not declining (FAO, 2018). Therefore, SSA agriculture needs to transform itself to improve the food security of the growing population and to provide a basis for economic growth and poverty reduction (Mwongera *et al.*, 2017). However, gradual climate change can threaten this transformation as it is predicted that climate change will potentially affect all pillars of food security if local temperature increases by 2°C or above (IPCC, 2014). Temperature changes and other extreme weather events are expected to increase crop failures, pest and disease outbreaks lead to declining and uneven yield trends with significant effects on household food security (Nyasimi *et al*., 2017).

Tanzania has been facing food insecurity problems and is among the thirteen countries in the world which are mostly affected by the impacts of climate change (IPCC, 2014). The average annual temperature in the country has increased by 1.0^0C while the annual rainfall has decreased by 2.8 mm per month per decade since the early 1960s. It is predicted that the mean daily temperatures will increase from 3°C to 5°C while the annual mean temperature is predicted to rise by 2°C to 4°C by 2050 (Chambura and Macgregor, 2009). In Mbeya and Songwe regions the annual mean temperature increased by 0.27◦C/decade since the 1960s with the variability of rainfall and frequent droughts (Craparo *et al.,* 2015). To improve food security, Food and Agriculture Organization (FAO) proposed CSA as an appropriate approach to increases agricultural productivity and income, improve adaptation to climate change, mitigate greenhouse gases and enhance the achievement of national food security under climate change (FAO, 2010).

Several CSA-practises have been promoted and used by farming households in Mbeya and Songwe regions. These include the use of crop-rotation which increases the adaptation capacity of agricultural systems to climate change by improving soil fertility and structure, soil water holding capacity and water and nutrients distribution through the soil profile, helping to prevent pests and diseases, and increasing yield stability (Kuntashula *et al*., 2014). Residue retention is another CSA-practise used by farming households as it enables preventing soil erosion, preserving soil moisture, avoiding compaction of the soil, containing pests and diseases, reducing CO_2 emission and increasing biodiversity in the agro-ecosystem (Chen *et al.*, 2019). Intercropping is also used to improve the use efficiency of land and available resources (water, light, and nutrients) through the different stages of growth. Furthermore, intercropping is a proven method to deter pests, encourage the proliferation of their natural enemies, reduce disease and insect injury, and inhibit weed growth through a "push-pull" system, making it an important aspect of CSA. The use of organic manure as well as the cultivation of legumes is equally fundamental in strengthening the resilience of farming households (Thornton and Lipper, 2013). In general, the usage of CSA-practises has an impact on food security as they assist farming households to increase food crop productivity (Lipper and Zilberman, 2018).

Apart from the promotion of these CSA-practises food security prevalence in Mbeya and Songwe regions is still high with statistics showing, 37.7 % of children below 5 years are stunted compared to the national level which is 34 % (TFNC, 2014). Surprisingly, the dietary diversity for children aged 6–23 months is documented to be an average of 2.1. The majority of the previous studies (i.e. Kassie *et al.,* 2014; Manda *et al.* 2015; Nkhoma *et al.* 2017; Pantaleo and Chagama, 2016; Nkhoma *et al.*, 2017; Dhraief *et al.* 2018) concentrated on the analysis of the impact of single practises on the household welfare. However, in reality, farming households use more than one practises as complements or substitutes that deal with their production constraints such as challenges of climate change (Teklewold *et al.,* 2013). For example, Wu and Babcock (1998) argued that analysing the usage and effect of the agricultural technologies on welfare without controlling for interdependence and simultaneously between them, there is a possibility of overestimating or underestimating the effect of several factors on the technologies used. Furthermore, farming households may decide to use multiple combinations of CSA-practises but it is not known which combinations result in the highest payoffs in terms of household food security.

There are various researches that examined the determinants and the effect of using multiple combinations of agriculture practises on household welfare which used a multiple setting framework elsewhere such a Teklewold *et al.*, 2020; Wekesa *et al.*, 2018; ongoing *et al*., 2018; Ng'ombe *et al.*,2017; Manda *et al.*, 2015 Teklewold *et al.*, 2013). Nevertheless, the Southern Highlands of Mbeya and Songwe might have different ecological set-up; hence, the usage and impacts of CSA-practises could be different. Additionally, in this study, crop rotation, intercropping and residue retention were used as CSA-practises mostly practised in the study area and little is known on the impact of these practises (especially when used in combination) on household food security. Therefore, this study aimed to fill these knowledge gaps by evaluating the impact of the combination of CSA- practises on household food security in Mbeya and Songwe regions using a multinomial endogenous switching regression framework.

The main contribution of this study to the body of knowledge is as follows. First, it articulates the importance of synergetic effects arising from the combination of CSA-practises in helping to achieve household food security in Tanzania. Second, the study investigated whether the usage of CSA-practises in combination would improve food security than using them in isolation. This knowledge is appropriate to the on-going discussions on whether farming households in Tanzania and elsewhere should use CSA-practises in piecemeal or in the package so as to improve household food security. The third is that the study extends the empirical and methodological approach in the literature by evaluating the impact of CSA-practises on food security while controlling for the selection bias, particularly in the Tanzanian context. Finally, the study is relevant for designing an effective extension policy by identifying the combination of CSA-practises that deliver the highest payoff specifically on food security.

The rest of the study is structured as follows: Section 2 of this study give a brief conceptual framework while section 3 presents the methodology, section 4 presents the results and discussions. The last section presents the conclusion, recommendations and policy Implications.

2.0 Conceptual Framework

According to Feder *et al.* (1985), agricultural practises can be introduced to farm households in packages and can be used either in combination or in isolation. This study examined whether the use of CSA-practises either in isolation or in combination can improve household food security. In practise, farming households usually use a combination of CSA-practises to tackle production constraints like low yields, droughts, weeds, pests and diseases resulting from climate change. The usage of CSA-practises either in isolation or in combination can be influenced by several factors such as household characteristics, resource constraints, plot characteristics, institution characteristics and geographical location. The decision to use CSA-practises either in isolation or in combination can improve agricultural productivity; hence increasing the availability of food. This can affect food prices in the local markets then affect household's food expenditure. Because of increased production and/or productivity, households can sell the surplus crop, which can increase increased household income. Increased income in turn could raise expenditures on different varieties of food, which are not produced by the household.

It is assumed that the aim of the farming households is to maximize utility V_{ij} by comparing the utility provided by alternative CSA-practises. A farm household i can use CSA-practise j over any alternative CSA-practise m, if $V_{ij} > V_{ik}, k \neq j$. However, farming households always self-select into the user or non-user categories and endogeneity problems may arise because unobservable characteristics may be correlated with the outcome variables. For instance, farm households can decide to use a CSA-practises based on unobservable characteristics such as their innate managerial, influences of policymakers and technical abilities in understanding and using the practise (Abdulai and Huffman, 2014). Therefore, failure to account for unobservable characteristics may overstate or understate the true impact of the CSA-practises (Kim *et al.*, 2019). Therefore, a multinomial endogenous switching regression model developed by Bourguignon *et al.* (2007) was applied to account for interactions between uses of alternative CSA-practises and self-selection bias.

3.0 Methodology

3.1 Study Area, Sampling, Data Collection

The study used cross-sectional data collected from a farm household survey in the Southern Highlands of Mbeya and Songwe in Tanzania. The sample covered 1443 farming households where multistage sampling was used to select respondents. First, the regions (Mbeya and Songwe) and districts (Mbarali, Mbeya rural Mbozi and Momba were purposively selected based on their food crop production potential (i.e. maize, paddy, common beans, and soya beans) and prevalence of food security. Second, proportional random sampling was applied to select 51 wards from 92 wards in four districts. Third, farmer organizations (FOs) from each ward were identified then members from each FOs were sampled using systematic random sampling to get a total of 1443 households. Different information were collected such as household demographics, socioeconomic characteristics, CSA-practises used, crop production, food consumption, and other farm- and farmer-specific characteristics.

3.2 A Multinomial Logit Selection Model

To examine the factors motivating farming households to use specific CSA-practises in isolation or in combination(s) (crop rotation, residue retention and intercropping) a multinomial logit selection model was employed. Assume that a latent variable A^* captures the expected food security (Food Variety Score per Adult Equivalent Unit) from using combination$j$ $(j = 1 \dots m)$ with respect to the usage of any other combination k. Therefore, the latent variable can be specified as follows:

$$A^* = \overline{V_{ij}} + \eta_{ij} = Z_i\alpha_j + \eta_{ij} \quad (1)$$

$$A = \begin{cases} 1\ iff\ A_{i1}^{*} > \max_{k\neq 1}(A_{ik}^{*})\ or\ \eta_{i1} < 0 \\ \quad\quad\quad\quad . \\ \quad\quad\quad\quad . \\ M\ iff\ A_{ij}^{*} > \max_{k\neq M}(U_{ik}^{*})\ or\ \eta_{iM} < 0 \end{cases} \quad (2)$$

This is to say, farming household i can choose a combination j if combination j provides expected food variety score per adult equivalent unit (FVS/AEU) as an outcome that is greater than any other combination ($\varepsilon_{ij} = \max_{k\neq j}(A_{ik}^{*} - A_{ij}^{*}) < 0$). A deterministic component ($V_{ij} = Z_i\alpha_j$) and the idiosyncratic unobservable stochastic component (η_{ij}) are shown in equation 1.

The latter captures variables that are essential to farming household decision-makers but are not known to the researcher such as skills or motivation. The deterministic component (V_{ij}) is the function of the factors (Z_i) that affect the likelihood of using a combination j. The (Z_i) variables include farm household characteristics (household size, education of the household head, gender of the household head, age of the household head, marital status of the household head and farming experience of the household head); households resource endowment (livestock ownership, mobile phone ownership, radio ownership, television ownership, income diversification, access to loan); plot characteristics (average plot distance, number of plots cultivated, soil erosion, production diversity and total plot size); institutional factors (access to demonstration plots, extension services, distance from home to the extension office, availability of tarmac road, membership in the multiple organizations); and geographical location (Mbozi, Momba and Mbarali districts).

It is assumed that covariate vector Z_i is uncorrelated with the idiosyncratic unobservable stochastic component η_{ij}. For example,$E(\eta_{ij}|Z_i) = 0$is under the assumption that $\eta_{ij}$are Independent and Identically Gumble distributed, that is under the Independence of Irrelevant Alternative (IIA) hypothesis. Selection model (1) leads to a multinomial logit model (McFadden, 1974) where the probability of choosing a combination j(P_{ij}) is given as:

$$P_{ij} = Pr(\varepsilon_{ij} < (0|Z_i) = \frac{exp(Z_i\alpha_j)}{\sum_{k=1}^{M} exp(Z_i\alpha_k)} \quad (3)$$

The second stage the study used the MESR to estimate the relationship between the outcome variables and a set of exogenous variables focused combinations. Based on the CSA-practises specification, the base category was the non-user of CSA-practises (i.e., $C_0R_0I_0$), is denoted as $j = 1$. In the remaining packages ($j = 2, \ldots, 8$), at least one CSA-practise is used. The outcome equation for each possible regime j is given as:

$$\begin{cases} Regime\ 1: Y_{i1} = X_i\beta_1 + \mu_{i1} \quad if\ A = 1 \\ \quad\quad\quad\quad . \\ \quad\quad\quad\quad . \\ Regime\ M: Y_{ij} = X_i\beta_j + \mu_{ij} \quad if\ A = j \end{cases} \quad (4)$$

$X_i$set of exogenous variables (household characteristics, households resource endowment, plot, household, institution factors and geographical location) for the chosen combination and μ_{ij} is the unobserved stochastic component which verifies $E(\mu_{ij}|X_{ij}, Z_{ij}) = 0$ and $var(\mu_{ij}|x_{ij}, z) = \sigma_j^2$. Note that, the outcome equations were estimated separately when estimating OLS models.

If the error term of the selection model (2) η_{ij} are correlated with the error term of the outcome equation μ_{ij} conditionally on the sample selection are non-zero and the OLS estimates are inconsistent. To correct for the potential inconsistency, the study employed the model by Bourguignon *et al*, (2007), which takes into account the correlation between error terms from each outcome equation μ_{ij}. This is a Multinomial endogenous switching regression model.

According to Bourguignon *et al.* (2007), the following selection bias-corrected outcome equation was used to get a consistent estimation of β_j in the outcome equation. In order to account for the heteroscedasticity in the second stage, the standard errors in equation 4 were bootstrapped. In addition, to identify equation 4, the selection instruments are required. However, in empirical work, it is hard to find a valid instrument. Therefore, for identification, the following selection instruments were used and excluded from the outcome equation (i.e. equation 4); average farm distance, extension visits, distance from extension offices, access to market, access to demonstration plot and access to loan. The admissibility test was conducted to check their validity (Di Falco & Veronesi, 2013) to confirm that these variables jointly affect usage of CSA-practises but they do not affect FVS/AEU of non-user of CSA-practises.

$$\begin{cases} Regime\ 1: Y_{i1} = X_i\beta_1 + \sigma_1\left[\rho_1 m(P_{i1}) + \sum_j \rho_j m(P_{ij})\frac{P_{ij}}{P_{ij}-1}\right] + V_{i1} \quad if A = 1 & 5a \\ \vdots \\ Regime\ M: Y_{iM} = X_i\beta_M + \sigma_j\left[\rho_1 m(P_{iM}) + \sum_j \rho_j m(P_{ij})\frac{P_{ij}}{P_{ij}-1}\right] + V_{ij} \quad if\ A = j & 5b \end{cases}$$

3.3 Estimation of Average Treatment Effects

Based on Bourguignon *et al.* (2007) the expected FVS/AEU of the farming household that used a combination of CSA practise$_j$ can be derived as follows:

$$\begin{cases} E(Y_{i2}|A_i = 2) = X_i\beta_2 + \sigma_2\left[\rho_2 m(P_{i2}) + \sum_{k\neq 2} P_{ik} m(P_{ik})\frac{P_{ik}}{P_{ik}-1}\right] & (6a) \\ E(Y_{iM}|A_i = M) = X_i\beta_M + \sigma_M\left[\rho_M m(P_{iM}) + \sum_{k\neq 2} P_{ik} m(P_{ik})\frac{P_{ik}}{P_{ik}-1}\right] & (6b) \end{cases}$$

Then the FVS/AEU of farming household that used combination $_j$ was derived in the hypothetical counterfactual case that did not use$(j = 1)$ as follows:

$$\begin{cases} E(Y_{i1}|A_i = 2) = X_i\beta_1 + \sigma_1\left[\rho_1 m(P_{i2}) + \rho_2 m(P_{i1})\frac{P_{i1}}{P_{i1}-1} + \sum_{k=3-M} \rho_k m(P_{ik})\frac{P_{ik}}{P_{ik}-1}\right] & (7a) \\ E(Y_{i1}|A_i = M) = X_i\beta_1 + \sigma_1\left[\rho_1 m(P_i m) + \sum_{k=2....M} \rho_k m(P_{ik-1})\frac{P_{ik-1}}{P_{ik-1}-1}\right] & (7b) \end{cases}$$

Therefore, the difference between equations $(6a)$ and $(7a)$ or equations. $(6b)$ and $(7b)$ give the average treatment effect (ATT).

3.4 Construction of Food Variety Score per Adult Equivalent Unit (FVS/AEU)

The households indicated whether they consumed one of the food items within a particular food group in the previous seven days. If the household indicated YES, the household received a value of one score and zero for NO response. The list is based on the 12 food groups, namely vegetables, fruits, meat, eggs, cereals, white tubers and roots, fish and other seafood, legumes and nuts, milk and milk products, oil and fats, sweets, and spices, condiments and beverages (FAO, 2011). FVS refers to the individual food items consumed over a particular period; a day, a week, or a month. In this study, FVS was computed based on a list comprising 47 individual food items within the same 12 food groups. The respondent indicated whether the household consumed or not within the previous 7 days.

The adult equivalent scale constant for East Africa standards (Massawe, 2016) was employed to compute households of different sizes with members of different sex and age groups. An adult equivalent unit was assigned to each household member by multiplying each age category by a respective adult equivalent scale with respect to the gender of each household member. This indicates that households with different sizes have different requirements in terms of resources, the sum of adult equivalent was adjusted based on the economies of scale constants (Mbwana *et al.,* 2016). The values were multiplied by the average costs subject to household sizes. The computed variable was then used as one of the predictors replacing the household size.

4.0 Results and Discussion

4.1 Impacts of CSA-practises Usage on Food Security

The treatment effect was determined to find the impact of CSA-practises usage either in isolation or in combination on food security. The ordinary least squares regression of FVS/AEU of the households were estimated for each CSA-practises (either in isolation or in combination), taking care of the selection bias correction terms. Different combinations were involved; crop rotation only ($C_1R_0I_0$), residue retention only ($C_0R_1I_0$) intercropping only ($C_0R_0I_1$) combination of crop rotation and residue retention ($C_1R_1I_0$), a combination of crop rotation and intercropping ($C_1R_1I_0$), a combination of residue retention and intercropping ($C_0R_1I_1$) and the crop rotation, residue retention and intercropping combination ($C_1R_1I_1$). The simplest approach is to look at the actual mean of FVS/AEU by farm household CSA-practises used. The result shows that farming households that used crop rotation in isolation have a food variety score of 2.0179/AEU while all other practises (i.e. in isolation or in combinations) were negative and have insignificant effect on FVS/AEU.

The above estimation does not account for both observed and unobserved characteristics that might influence FVS/AEU). Therefore, the counterfactual analysis was conducted to address both observed and unobserved characteristics as explained in section 3.3. That is the difference in the FVS/AEU that might be caused by unobservable characteristics. The analysis helps to examine which combinations of CSA-practises have a higher impact on FVS/AEU. Table 1 presents the FVS/AEU under actual and counterfactual situations. Column (3) of Table 1 shows the usage effect of each CSA-practise on FVS/AEU, which is the treatment effect, calculated as the difference between columns (1) and (2) based on equations (6a – 7a) and 6b – 7b) as shown in section 3.3.

The results show that the impacts of CSA-practises on food security (FVS/AEU) are both positive and negative but differ in magnitude depending on the practise used. Farm household that used CSA-practises such as crop rotation, residue retention and intercropping in isolation increases the FVS/AEU by a magnitude of 2.6213, 0.9349 and 3.7076 respectively. The finding is similar to the study by Al-Shater *et al*. (2017) in Syria, which found that farming households that used zero tillage in isolation as conservation agriculture practise earned on the average 9494 SYP or US$189 per ha (33% higher) net income. The result is also inconsistent with that of Beyene *et al.* (2017) in Ethiopia which found that farm households that used soil conservation practises in isolation reduced net revenue by a magnitude of 101.7Birr per hectare. The study found that usage of crop rotation and residue retention ($C_1R_1I_0$) in combination does not guarantee the maximum return. This is because farm households that used a combination of crop rotation and residue retention, their FVS/AEU increased by a magnitude of 0.3517 compared to non-users. However, the usage of crop rotation ($C_1R_0I_0$), residue retention ($C_0R_1I_0$) and the intercropping ($C_0R_0I_1$) increase FVS/AEU of a magnitude of 2.6213, 0.9349 and 3.7076, which are higher than the usage of a combination of crop rotation and residue retention ($C_1R_1I_0$).

This means that using CSA-practises in isolation improves household food security than used in combination. The finding is inconsistent with that of Beyene *et al.* (2017) who found that the usage of a combination of soil conservation and intercropping increased the net revenue per hectare. The result of this study cautions about the conclusion that multiple uses are not always the best CSA-agriculture to improve household food security. It is possible to use a combination of CSA-agriculture, relative to using one practise at a time, which places burdens on farming households in terms of expenditure and risk.

Table 1: Impact on Food Variety Score by Climate Smart Agriculture practises

CSA-practise	FVS/AD if farm households did use	Counterfactual FVS/AD if farm households didn't use	Usage Effects (FVS/AD)
Crop rotation only	1.9458 (0.2792)	-0.6756 (0.1433)	2.6213*** (0.1631)
Residue retention only	0.2410 (0.0112)	-0.6939 (0.0188)	0.9349*** (0.0150)
Intercropping only	0.1077 (0.0152)	-3.5999 (0.0855)	3.7076*** (0.0807)
Combination of crop rotation and residue retention	0.1062 (0.0110)	-0.2455 (0.0209)	0.3517*** (0.0186)
Combination of crop rotation and Intercropping	-10.2866 (0.1628)	-1.0341 (0.0943)	-9.2526*** (0.2247)
Combination of residue retention and Intercropping	0.1736 (0.0029)	0.4655 (0.0064)	-0.2918*** (0.0056)
Combination of crop rotation, residue retention and intercropping	0.2417 (0.0025)	0.2412 (0.0028)	0.0005*** (0.0018)

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

The study found that usage of combination of all three practises simultaneously was positive and significantly increased the FVS/AEU. Again, using all three practises simultaneously ($C_1R_1I_1$) does not guarantee maximum improvement of household food security as it has a lower magnitude compared to the practises used in isolation. The study found that farming households that used a combination of crop rotation, residual retention and intercropping ($C_1R_1I_1$) increased food variety score by a magnitude of 0.0005 per AEU. However, using a combination of crop rotation and residue retention (C1R1I0) increases the food variety score by a magnitude of 0.3517 per AEU which is higher than using crop rotation, residue retention intercropping in combination ($C_1R_1I_1$). The finding is similar to the study by Di Falco and Veronesi (2013), who found that a combination of soil conservation and changing crop varieties yielded a better return than the usage of three strategies: crop rotation, water conservation, and soil conservation in rural Ethiopia. Results of this study indicate that the payoff from combinations of CSA-practises depends on the type of practises considered in the analysis, as there is a possibility that using CSA-practises in isolation may yield a better payoff than combinations of practises.

5.0 Conclusion, Recommendations and Policy Implications

Usage of CSA-practises and evaluation of their potential impacts on household welfare have received considerable attention from policy analysts. Low rates of usage among farmers continue to be recorded despite substantial investments in their promotion by governments and other stakeholders. Furthermore, prior research has ignored joint usage and interdependence of multiple CSA-practises and their potential impacts on household food security. Using cross-sectional data collected from Mbeya and Songwe regions in Tanzania, the study evaluated the impact of using combination of CSA-practises on food security among farming households. A multinomial endogenous switching regression model was used to account for self-selection.

With respect to the findings of the causal effects, the study recommends as follows. First, usage of CSA-practises both in isolation and in combination should be encouraged because all possible combinations result in significant positive effects on food variety per adult equivalent unit as an indicator of food security except for crop rotation and intercropping and residue retention and intercropping combination. Second, more promotional efforts should focus on the usage of CSA-practises in isolation since these generally increase food varieties score per adult equivalent compared to CSA-practises used in combinations. Further, regardless of unobserved and observed effects, using crop rotation, residue retention and intercropping in isolation results into the highest food variety score per adult equivalent among all possible combinations. Therefore, efforts to improve food variety score per adult equivalent unit should focus on the usage of crop rotation and residue retention and intercropping in isolation.

The findings of this study are grounded on cross-sectional data. Therefore, better data sets such as panel data methods with time dimensions should be considered in future studies for more rigorous evidence about the role and implications of CSA practises. Additionally, the data used in this study are not ideally rich in agronomic and shock variables. Admittedly, this is an important limitation, plus our study is restricted to evaluating the potential contribution of the usage of CSA-practises on household food security; perhaps these results could be different under a single crop or when all input costs are ideally observed. Besides, CSA-practises could be dynamic or agro-ecological location-specific: some practises could be more effective in the short run while others yield more payoffs in the long run or maybe their impacts vary by agro-ecological location. These should be investigated and future research should be conducted to address these issues.

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