THE INTERNATIONAL JOURNAL OF HUMANITIES & SOCIAL STUDIES

Effects of Zai Pits and Half-Moon Technologies on Smallholder Farmers' Income in Kita Cercle, Mali

Ayouba Coulibaly
Agricultural Economist, Department of Agricultural Economics and Agribusiness Management, Egerton University, Kenya

Abstract:
Smallholder farmers, who mastered the agricultural production in Mali and elsewhere, are the most vulnerable to the drawback of the soil degradation and rainfall shortage. A range of practices such as Zai pits and Half-moon technologies can tackle these issues for better livelihood of these farmers. Despite the multiple benefits of Zai pits and Half-moon, there is a lack of understanding of farmer's behaviours and the potential economics of Zai pits and Half-moon. The objective of this paper was to determine the effects of Zai pit and Half-moon technologies on smallholder farmers' income in the Cercle of Kita in Mali. An exploratory research design was adopted to collect data from 280 users and non-users. We applied descriptive statistics and Multinomial Endogenous Switching Regression Model (MESRM) to analyse the data. The socio-economic and institutional variables with regard to Zai pits and Half-moon were determined as influencing smallholder farmers' income. In addition, others factors such as distance to nearest market, contact with extension services providers, farm assets, farmers' perception on soil erosion, fertility of the plot, farmers' perception on soil erosion and risk-attitude were found to be positively affecting the choice of Zai pits and Half-moon use. The users of Zai pit, Half-moon and Zai-Half-moon earn 74.42$, 28.29 and 195.32$ respectively) more income from the main crop and 278.15$, 79.99 and 759.82$ more from the general household income than non-users. The study recommended increasing farmers' sensitization on both technologies as well as their ability to invest in farming business through information sharing and improving perception on the characteristics of the two technologies. There is also need to improve farmers' business skills in innovativeness, risk-taking attitude, and management skills ability of climatic information analysis since they enhance the demand for Zai pit and Half-moon technologies.

Keywords*: Smallholder farmers, zai pits, half-moon, multinomial endogenous switching regression, incomes, technology-users and non-users*

1. Introduction

Agriculture constitutes the engine of Malian economy contributing to 41% of the Gross Domestic Product (2015/2016); with an employment of around 75% of the population(World Bank, 2015).Rainfall shortage and land degradation due to soil erosion and soil fertility depletion remains the main challenges to the agricultural development. Thatland degradation negatively affected soil fertility, production capacity, soil biodiversity and natural resources. These points were noted by researchers (Duncan, 2016; Blaikie and Brookfield, 2015) who argue that these factors combined remains the key environmental issues and threat to the well-being of smallhol derfarmers' households in sub-Saharan African countries.Therefore, smallholder farmers are the most vulnerable to the drawback of the soil degradation and rainfall shortage due to an exacerbated food insecurity and poverty of communities (Hellmusth et al., 2009). To tackle theseissues, a range of practices such *Zai* pits, Half-moon, stone terraces, soil bunds and area closures were introduced into both individual and community lands management. TheSoil and Water Conservation Technologies (SWCTs) were the main pathways to improve farm production and farmers' general incomes through improved resilience to climate shocks(Ayande*et al*., 2018). Among the SWTs,*Zai* pitsand Half-moon are the most widely spread and used to their convenience to farmers' socio-economic conditions (Abdulai and Huffman, 2014).

Furthermore, the potential benefits of *Zai* pit and Half-moon have been proved not only in soil and water conservation but also in increasing soil fertility and reduction of plant disease, weeds, and insects (Manda *et al*., 2016). *Zai*pit and Half-moon technologies have similarity in both benefits and requirement. The latter requires relatively bigger land size and is more labour intensive. The indirect effects of these technologies are their positive impact on improved household welfare through stable food security and biodiversity (Yosef and Asmamaw, 2015).

Despite the multiple benefits of *Zai* pits and Half-moon and the considerable efforts made by national and international organizations to incentivize small holder farmers to invest in these technologies, there is a limited empirical knowledge on factors influencing the choice of these two technologies and their effects on farmers' incomes. An improved understanding of farmers' choice behavior and the potential economics of a given technology particularly *Zai* pitand Half-moon is necessary since it determines farmers' returns to investment in the technology and making appropriate policies (Larson *et al.,* 2014). This understanding is also important for sustainable intensification of the two technologies in the region. Therefore, this research is aimed at examining the determinants of the choice and effect of *Zai* pitsand Half-moon technologies on smallholder farmers' incomes in Kita Cercle, Mali.This paper is organised as follow: section 2 presents the material and methods; section 3 provides the results and discuss them; lastly, section four concludes the findings of the study and makes subsequent recommendations.

2. Materials and Methods

2.1. Study Area; and Sampling and Data

This study was conducted in Kita Circle located in the South-western part of the Republic of Mali.Its geographical coordinates are 13° 15' North, 9° 20 West and covers an area of 35.250 km^2 with a total population estimated in 2012 at 4,565,763 and 33 communes (Sangho *et al.*, 2015). The study area has rainy season has rainfall of 500-700 mmscattered between 3 and 4 months and followed by a prolonged drought.

The study used multistage sampling procedure where Kita Cercle was selected purposively with three clusters: Kita Cercle, communes and villages. At the first level, seven villages from four communes of Kita Cercle were selected purposively based on the potential practice of *Zai* pitsand Half-moon technologies. At the second level, a linear sampling technique was used to randomly select 280 respondents from a list of smallholder farmers available at local extension services office. The sample size in each village and group of users and non-users was determined using the probability proportional to size (See Table 1). Semi-structured questionnaire was used to collect data throughface-to-face interview. A pre-test of the questionnaire was first carried out to determine the reliability and validity of the questionnaire.

Villages	Mansala	Djougounté	Kakoro-Moutan	Sakora	Kabé	Doumba-Djiala	Marena
Number of smallholder farmers	68	200	135	64	268	65	130
Sample Size	20	60	41	19	81	20	39

Table 1: Sample Size per Selected Village

2.2. Modelling Effects of Zai Pit and Half-Moon Technologies on Smallholder Farmers' Income

In this study it is assumed that a farmer *i* decides to use RWHTs J to maximize his or her expected profit if the RWHTs J provide higher expected profit (Vij) than any other alternative RWHTs combination (Vim).

The econometric specification of the model is given in its latent as:

$$V^*_{ij} = X'_{ij} + n_{ij} = X_i \beta_j + n_{ij} \text{ ; j=1, 2, 3, 4} \quad \text{.......(1)}$$

The study used the multinomial endogenous switching regression model proposed by Deb and Trivedi, (2004). The first stage of this model (multinomial logit selection model) was used to determine the choice of socio-economic, institutional, perceived technology attributes and climate characteristics influencing smallholderfarmers decisions of *Zai* pitand Half-moon technologies uses. The estimation of Average Treatment Effect on the Treated (ATT) was used in the second stage to determine the effects of *Zai* pit and Half-moon technologies on smallholderfarmers' income.

A multinomial endogenous switching regression (MESR) approach following Bourguignon *et al*. (2004) model to correct selection bias was used. This framework offers several advantages over the multivariate probit model: it has the benefit of evaluating alternative combinations of uses as well as individual uses, it also addresses both problems of self-selection bias and the interactions between choices of alternative uses(Mansur *et al.,*2007). In contrast to MESR models, the multivariate probit model is limited by the difficulties in model calibration. In addition, there is no guarantee for a global maximum in the likelihood function and the computation of probit probabilities for K choice alternatives requires the evaluation of a (K-1) variant cumulative normal (Kamakura, 1989). Modelling the effect of practicing *Zai* pit and Half-moon technologies on the income under the MESR framework proceeds in two stages. The first stage used the multinomial logit model to determine the choice while the ATT was used at the second stage to determine the effects of choice on the income.

The probability of i farmers with characteristics X to choose j technologies is specified by a multinomial logit model (McFadden, 1973) which can be express as thus:

$$P_{ij} = \Pr\,(n_{ij} \prec 0 \;/X_i) \;\; \frac{\exp\,(X_i\beta_j)}{\sum_{m=1}^{j}\exp\,(X_i\beta_m)} \quad \text{.......(2)}$$

Following Di Falco *et al.* (2011) and Teklewold *et al.* (2013), the ATT in the actual and counterfactual can be computed as follow:

Users with use characteristics (actual)

$$E(Z_{i2} \;\; /I = 2) = Q_i\alpha_2 + \delta_2 \lambda_2 \quad \text{.......(3a)}$$

$$E(Z_{ij} \;\; /I = J) = Q_i\alpha_j + \delta_j \lambda_j \quad \text{.......(3b)}$$

Users, had they decided not to use (counterfactual):

$$E(Z_{i1} \quad / I = 2) = Q_i\alpha_1 + \delta_1 \lambda_2 \text{ ......(4a)}$$

$$E(Z_{i1} \quad / I = J) = Q_i\alpha_1 + \delta_1 \lambda_j \text{ ......(4b)}$$

These expected values can be used to derive unbiased estimates of the ATT. Therefore, it allows for calculating the Average Treatment effects (ATT) as the difference between equations (3*a*) and (4*a*) or (3b) and (4b).

$$ATT = E(Z_{i2} / I = 2) - E(Z_{i1} / I = 2) = Q_i\alpha_2 + \delta_2 \lambda_2 - Q_i\alpha_1 - \delta_1 \lambda_2 = Q_i(\alpha_2 - \alpha_1) + \lambda_2 (\delta_2 - \delta_1) \text{ ....(5)}$$

The first term on the right-hand side of equations (5) represents the expected change in farmers' income, if the characteristics and resources of users had the same returns (coefficients) as the returns on the characteristics and resources of non-users. The second term on the right-hand side (λ_j) is the selection term that corrects all potential effects of the difference in the selection bias from unobserved characteristics. The determinants of the choice of *Zai* pits and Half-moon technologies uses were derived from previous related studies (Kassie *et al*. 2012; Aubert *et al*. 2012; Teklewold *et al.* 2013; Muna *et al.* 2017).

3. Results and Discussion

3.1. Preliminary Diagnostics of the Variables to Be Used in the Regression Model

Preliminary diagnostics for multicollinearity and heteroskedasticity issues were conducted on variables of socio-economic, institutional, technology attributes and climate characteristics. The results of both pair-wise correlation and variance inflation factor results confirmed that there was no strong linear relationship among the continuous explanatory variables tested as indicated in Table 2 and Table 3 (Wu, 2016; Akinwande *et al*., 2015).

Variable	VIF	1/VIF
Age of the household Head	4.51	0.22
Household size	2.80	0.36
Number of people in economics activities	2.50	0.40
Distance to the nearest market	2.09	0.48
Education level of household head	1.17	0.85
Number of training	1.29	0.77
Number of extensions	1.82	0.55
Land size	1.55	0.64
Value of assets	1.15	0.87
Value of off farm income	1.17	0.85
Value of credit Amount	1.35	0.74
Farmers’ risk-taking attitude	1.96	0.51
Livestock ownership in tropical livestock Unit	1.34	0.75
Farmers’ perceptions of timeliness	1.86	0.54
Perception of ease of use of technology	1.88	0.53
Perception of compatibility of technology	1.72	0.58
Perception of farmers innovativeness	1.47	0.68
Perception of resource availability	1.20	0.84
Level of trust in institution	1.07	0.93
Mean VIF	1.89	

Table 2: Variance Inflation Factor Test Results

	Gender	Group	Land Tenure	Slope	Fertility	Erosion	Usefulness	Village
Gender	1.00							
Group	0.03	1.00						
Land tenure	-0.02	-0.09	1.00					
Slope	-0.08	0.14	-0.08	1.0				
Fertility	-0.01	0.03	-0.01	-0.01	1.00			
Erosion	0.02	0.10	0.10	0.01	0.11	1.00		
Usefulness	0.00	0.07	0.01	0.05	-0.23	0.28	1.00	
Village	0.13	0.08	0.01	-0.03	-0.07	-0.06	0.04	1.00

Table 32: Pair-Wise Correlation Test Results for Categorical Explanatory Variables

3.2. Descriptive Statistics

3.2.1. Socio-Economic and Institutional Characteristics of Smallholder farmers

The difference between female-headed and male-headed households was significant at 10%. The male-headed household was the most dominant in the study area. There usually exist gender-specific constraints faced by female-headed households such as dominant culture that males still have exclusive rights to make farm decisions. Further, security of land tenure in Kita district for women is not guaranteed which could deny them access to important facilities like credit. Users were significantly younger than non-users at 10% level of significance. This imply that younger farmers are explorative and innovative and they may seek to try new and improved agricultural technologies compared to older farmers who might be more conservative.

There was a significant difference at 5% level in off-farm income earned by non-users and users. Households with more off-farm income are less likely to use technologies, suggesting that income could cause households to invest in other activities such as commerce rather than in agricultural production. Farmers' risk attitude towards technology attributes was found to be very strong and extremely strong for non-users and users, respectively. This indicates that users had higher risk attitude compared non-users. Users had a longer distance to the nearest market compared to non-users with a significance difference at 1% level. Distant farmers with a limited access to the markets often rely on agricultural activities which require fewer inputs such as *Zai* and Half-moon uses.

There was a significant difference in the number of contacts with extension service providers between non-users and users at 1% significance level. The uses of *Zai* pit and Half-moon requires technical information, thus frequent advice from extension services.

Variables	Variable Description	Mean Values				T-Test Value
		Non-Users (N=72)	Std. Err.	Users (N=208)	Std. Err.	
Farmers Characteristics						
Gender	Gender of the household head (1=Male)	0.96	0.02	0.99	0.01	-1.77*
Education	Years of schooling of household head (number)	1.65	0.47	1.29	0.20	0.84
Age	Age of the household head (number)	52.35	1.62	48.97	0.97	1.77*
Household size	Number of household members (number)	12.88	1.23	11.81	0.71	0.76
Off-farm income	Revenue from non-farming activities (000 FCFA)	69.43	10.84	42.86	4.80	2.57**
Risk attitude	Household head risk attitude toward technologies	3.62	0.11	4.23	0.05	-5.65***
Institutional Characteristics						
Group membership	Household head's being member of a farmer group (1=Yes)	0.24	0.05	0.30	0.03	-1.08
Distance to nearest market	Distance from household home to nearest output market (minutes walking)	75.88	11.75	128.86	8.24	-3.39***
Number of extension service	Household head's access of extension services (number)	1.85	0.18	3.10	0.16	-4.38***
Number of agricultural training	Household head's attendance of agricultural training (number)	0.72	0.09	1.23	0.06	-4.31***
Trust in institution	Household level of trust in available institutions (1= disagree)	3.99	0.08	4.06	0.05	-0.65
Plot Characteristics						
Livestock ownership	Livestock owned by household head (tropical livestock unit-TLU)	2.57	0.46	1.86	0.14	1.97**
Farm asset value	Monetary value of farm properties (in 000 FCFA)	350.94	23.39	333. 84	15.31	0.58
Farm size	Total land owned by household head (Hectare)	2.23	0.16	2.25	0.09	-0.17

Variables	Variable Description	Mean Values				T-Test Value
		Non-Users (N=72)	Std. Err.	Users (N=208)	Std. Err.	
Climate Related Characteristics						
Perception of timeliness	Household head's perception on timeliness of rainfall (1 = disagree)	3.02	0.15	3.33	0.07	-2.11**
Soil erosion	Household head's perception on soil erosion (1 = less eroded)	1.40	0.08	2.03	0.04	-7.75***
Soil slope	Household head's perception on slope of soil (1 = flat slope)	1.35	0.06	1.30	0.04	0.63
Soil fertility	Household Head's Perception On Soil Fertility(1= Less Fertile Plot)	1.79	0.08	1.48	0.04	3.89***
Technological Characteristics and Attribute						
Compatibility of technology	Household head's perception on technology compatibility (1= disagree)	3.53	0.15	4.27	0.06	-5.62***
Ease of use of technology	Household head's perception on the ease of use of technology (1 = disagree)	3.12	0.12	3.87	0.05	-6.79***
Innovativeness	Household head level of Innovativeness (1 = disagree)	3.97	0.10	4.39	0.04	-4.99***
Resource availability	Resources availability (1 = disagree)	1.68	0.09	2.03	0.07	-2.65***
Usefulness of technology	Usefulness of Zai pit, Half-moon (1 = disagree)	2.19	0.09	2.42	0.04	-2.76**
N	Number of observations	72	208			

Table 3: Descriptions and Summary Statistics of Variables Used in the Analysis
*Note: ***, **, * Significant at 1%, 5% and 10% Levels, Respectively; 000 FCFA* **=** **1000*

Regarding the number of agricultural training, users had more training than their counterpart at 1% significance level. The importance of training among users is plausible due to the nature of the technologies which require some technical knowledge. The Tropical Livestock Unit (TLU) was significant different at 5% level of significance between non-users and users. The livestock holding may act as a supplier for organic fertilizer as livestock contributes to manure applied *Zai* pits and Half-moon users.

Farmers' perception of timeliness of rainfall was significant different between users and non-users at 5% significance level. The users had relatively "Strong" perception than non-users vis-à-vis the timeliness, adequacy and distribution of rainfall. There was a significant difference in farmers' perception of soil erosion between non-users and users at 1% level of significance. The users were quite responsive in countering the effects of severe soil erosion by implementing RWHTs.

The difference in perception of soil fertility between users and non-users was significant at 1%. These results suggest that farmers who perceived their soil being poor fertile favourably dispose them to use *Zai* pit and Half-moon technologies. Perception of technology compatibility was statistically different at 1% significant level between non-users and users. The users were more positive towards the perception of *Zai* pit and Half-moon compatibility as consistent with the existing values of their socio-economic conditions. Regarding the ease of use characteristics, there was a statistical difference between the users and non-users at 1% significance level. Users had more favourable perception of the ease of use of *Zai* pit and Half-moon technology, hence their higher demand.

A comparison of farmers' innovativeness revealed significant difference between non-users and users at 1% significance level. The users were scaled at the highest level "Extremely Strongly" while the non-users are scaled are second last level "Very Strong". There was significant difference in the perception of resource availability between users and non-users at 1% significance level. The users saw resources at their disposal not only as opportunities but also sufficient for venturing in technology uses. In terms of usefulness of *Zai* pit and Half-moon technologies, there was a significant difference at 1% level between users and non-users. The users perceived more positively that the use of *Zai* pits and Half-moon technologies can improve their farming operations.

3.2.2. Confirmatory Factor Analysis for Technology Attributes and Climate Related Factors

The Confirmatory Factors Analysis (CFA) as a method of Principal Component Analysis (PCA) was applied for variable reduction purposes. The Weighted Mean (WM) was used to generate the scores for technology attributes and climate characteristics among user and non-users. A total of 24 self-estimation items were used to measure the latent constructs such are perception of timeliness, risk taking attribute, ease of use, compatibility, level of trust in institution, users' innovativeness and perceived resources availability. Post-estimation tests were carried out to ensure the Internal Consistency Reliability, Indicator Reliability and Convergent Validity of the selected constructs. The results of this analysis showed good fitness of the model while the KMO, Cronbach's alpha and Bartlett sphericity test indicated sample adequacy, reliability and relevance of items respectively, see Appendix 1(Tee and Wang (2017).

3.3 Results of Regression Analysis

3.3.1. Determinants of the Choice of Specific RWHT Uses and Its Effect on Smallholder Farmers' Incomes Determinants of the Choice of Specific RWHT Uses

The marginal effects from the ML model measured the expected change in the probability of a particular choice being made with respect to a unit change in an independent variable. This result is reported in Table 4. The base category is non-use upon which the results comparisons are made. The results showed three sets of parameter estimates, and one for each mutually exclusive combination of strategies. The model fits the data very well with the Wald test $\left[\chi^2(280) = 128.03; p = 0.000\right]$, implying that the null hypothesis that all regression coefficients are jointly equal to zero is rejected. Therefore, these results showed that the estimated coefficients differ substantially across the alternative uses.

	ZP			HM			ZP-HM		
Variable	**COEF.**	**SE**	**DY/DX**	**COEF.**	**SE**	**DY/DX**	**COEF.**	**SE**	**DY/DX**
Gender (Male =1)	1.538	1.366	0.196	0.841	1.510	-0.053	2.272	2.024	0.101
Age of household head	-0.019	0.018	-0.003	-0.006	0.020	0.001	-0.017	0.021	-0.001
Education level of household	-0.066	0.072	-0.009	-0.077	0.092	-0.005	0.01	0.080	0.008
Household size	0.049	0.028	0.008	0.005	0.045	-0.005	0.046	0.032	0.002
Group membership	0.257	0.555	0.095	0.064	0.621	-0.004	-0.53	0.669	-0.079
Distance to nearest market	0.006	0.003	0.001*	0.005	0.003	0.001	0.002	0.004	-0.001
Number of extension service	0.088	0.150	-0.011	0.093	0.166	-0.003	0.301	0.172	0.028**
Number of training	0.816	0.412	0.060	0.876	0.439	0.031	0.68	0.458	-0.003
Log value of assets	-0.817	0.229	0.055**	-0.776	0.235	-0.011	-0.88	0.247	0.024*
Log value of off-farm income	-0.018	0.053	0.002	-0.064	0.058	-0.008	-0.005	0.060	0.003
Trust in institution of farmer	-0.051	0.308	0.020	-0.063	0.331	0.005	-0.336	0.348	-0.036
Tropical livestock Unit-TLU	0.026	0.112	0.010	-0.090	0.133	-0.009	-0.079	0.107	-0.006
Perceptions of timeliness	-0.232	0.293	0.022	-0.318	0.341	-0.008	-0.606	0.359	-0.048
Riske-taking attitude	-0.333	0.351	-0.181**	0.758	0.492	0.140**	0.283	0.455	0.041
Farm characteristics									
Farm Size	-0.256	0.231	-0.082**	-0.150	0.261	-0.008	0.427	0.255	0.076
Erosion of Plot	1.749	0.389	0.126*	1.306	0.450	0.040	2.255	0.479	0.106**
Slope of Plot	-0.403	0.484	-0.052	-0.138	0.536	0.031	-0.430	0.550	-0.018
Fertility of Plot	-1.269	0.429	-0.046	-1.228	0.476	-0.008	-1.854	0.535	-0.096**
Technological characteristics and attribute									
Compatibility of technology	-0.082	0.281	0.045	-0.126	0.355	0.007	-0.667	0.362	-0.072
Ease of use of technology	1.075	0.395	-0.016	1.167	0.462	0.012	2.106	0.518	0.144
Innovativeness of farmers	0.732	0.461	0.234	-0.415	0.450	0.133	-0.133	0.520	-0.063
Resource availability	0.222	0.283	0.055	-0.181	0.329	0.056	0.229	0.311	0.016
Usefulness of the technology	0.943	0.293	0.047	1.238	0.390	0.071	0.787	0.390	-0.010
Regression diagnostics for ML model Number of observations 280 Log likelihood -252.4599 Wald chi2 (69) 128.03 Prob > chi2=0.0000									

Table 4: Results of Multinomial Logit and Marginal Effects for the Choice of Rwhts
*Notes: ***, **, *, Indicates Significance Level at 1%, 5% and 10% Respectively; SE=Standard Error; Zp= Zai Pit; Hm=Half-Moon; Zp-Hm=Zai Pit and Half-Moon Combined*

Distance to nearest market positively influenced usage of *Zai* pit use at 10% level of significance. Being close to the market facilitates access to inputs and market for output since it affects their transaction costs. Difficultly in accessing the market and inadequate infrastructure may make farmers more likely to participate in agricultural technology that require less inputs or focus more on local and available inputs. Therefore, the high likelihood of deciding to use *Zai* pit in their farm. Gebremariam and Tesfaye (2018) noted that distance to the nearest market had a negative effect on chemical fertilizer adoption but a positive effect on the adoption of organic fertilizers and crop rotation as presented by *Zai* pit use.

The number of contacts with extension service providers had a positive and significant influence on the usage of Zai-Half-moon uses at 5% level of significance. In this respect, agricultural extension services are the basic sources of information for smallholder farmers' awareness about soil degradation and the way in which it can be tackled, thus affecting their option for use of *Zai*-Half-moon combination. This is consistent with the findings of Nyangena and Juma (2014) who reported that increased contact with extension service providers increased farmers' knowledge and awareness of SWC technologies. This affects positively the level of adoption of such technologies.

The results in Table 4 revealed a positive and significant influence of the farm production assets on usage of *Zai* pit and *Zai*-Half-moon RWHTs by 5.5% and 2.4%, respectively. This result indicated that resource endowed farmers were more likely to largely use *Zai* pits and Zai-Half-moon as opposed to non-users. This is likely because farmers with higher asset value not only prefer more capital-intensive technologies but also can afford them. In line with this, Kersting and Wollni, (2012) noted that wealthier farmers are in a better position to face production and marketing risks and increasing farm liquidity which are determinant factors in agricultural technology adoption

With regard to farmer risk attitudes, there was a negative influence on the usage of *Zai* pit and a positive influence on the usage of Half-moon. The risk-takers have higher expectation of gains from the technologies. The Half-moon is comparatively considered riskier than *Zai* pitsince it requires more investment in terms of labour and land size. Therefore, farmers having a high-risk attitude are more likely to go for the usage of Half-moon. Previous studies (Deressa *et al*., 2008; Cooper and Coe, 2011) found a statically significant relationship between adoption of chemical fertilizer, improved seeds, pesticides and farmers risk-taking behaviour of farmers.

The model results revealed that the farm size had a negative and significant influence on the use of *Zai* pit use by 5% level of significance. This explained that farmers with a larger plot size were less likely to use *Zai* pit compared to non-users. This is probably due to *Zai* pittechnology being more labour intensive but also it is the most convenient for small plots compared to other technologies. This result is supported by Mango *et al*. (2017) who reported that ownership of more pieces of land was positively associated with greater wealth and increases availability of capital resources, which increase the likelihood of farmers making investment in land, soil and water conservation measures

Farmers' perception of soil erosion severity positively influenced use of *Zai* pit and *Zai*-Half-moon at 10% and 5% level of significance, respectively. Farmers with higher perception on soil erosion are more likely to solve the erosion issues by implementing multiple strategies, thus the use of *Zai* pit and *Zai*-Half-moon. In concordance to this, Haghou *et al.* (2014) found a positive correlation with adoption of soil conservation technology to solve soil degradation.

Farmers' perception towards soil fertility negatively and significantly influenced the joint use of *Zai*-Half-moon technologies at 5% level of significance. *Zai*-Half-moon technology is primary used as soil management strategy with the aims to reduces land degradation, improve poor soil quality thus enhance farm productivity. Therefore, it most preferences by farmers on poor fertile soil as oppose to good fertile soil. Manda *et al.* (2015) found that the propensity to adopt sustainable agricultural practices such as improved maize was high on fertile soils than low fertile soil, because most improved maize varieties required the application of expensive inorganic fertilizers.

3.3.2. Average Treatment Effects of Zai Pit and Half-Moon Uses

After determining the drivers of the choice of RWHTs uses in the first stage, average treatment effects were determined in the second stage. Table 5 presents results of the effect of RWH uses on income from the main crop and the general household income. For comparison purposes, the outcome variables are estimated under actual and counterfactual conditions. In Table 5, X represents the treated group (the users) and Y represents untreated (non-users), $\alpha1$ represents treated characteristics (use status) and $\alpha2$ untreated characteristic (non-use status). The level of effect is the difference in outcome from yield of the main crop and household income as a result of usage of the specified use. Therefore, effect on the treated characteristic (ATT) is $\alpha1(X\text{-}Y)$, while the one for untreated characteristic (ATU) is $\alpha2(X\text{-}Y)$. The treatment effect or returns effect on the treated is $X(\alpha1\text{-}\alpha2)$, while the one of untreated is $Y(\alpha1\text{-}\alpha2)$. The impact is considered as result of the difference between treated with treatment characteristics and the untreated with non-treatment characteristics $(\alpha1X)$ - $(\alpha2Y)$.

The ATT effects indicated that, on average, users of any RWHTs had higher income from the main income than non-users and the results are positive and statistically significant for all the combinations. The same is true for the general income of household. Therefore, making a simple comparison is misleading because it does not account for both observed and unobserved factors that may influence outcome variables. This significant difference in income from the main crop and general household income could be attributed to unobservable characteristics such as farmers' managerial abilities or soil quality. This issue is addressed by estimating a multinomial endogenous treatment effects model. Thus, outcome variables of farmers who used the RWHTs are compared with the outcome variables if they had not used. At the same time, the outcome variables of farmers who did not use RWHTs are compared with the outcome variables if they could have used the RWHTs.

The results reveal that, in all cases, users of RWHTs had a significant and positive impact on income from main crop and general household income compared to the counterfactual scenario (non-use). This implied that farmers who used RWHTs actually would have earned less if they had not used. In the counterfactual case, farmers who did not use the RWHTs but considered as users would have earned more from the use of the technologies. Additionally, RWHTs use as a combination had a significant and positive effect on the main crop yield and household general income compared to those who used them separately. This is consistent with other studies on adoption of multiple agricultural technologies (Teklewold *et al*., 2013; Arslan *et al*., 2015; Manda *et al.,* 2015). Further, the average treatment effect (ATT) results indicate that RWHTs use significantly enhances the household income from main crop and household general income for users. The average treatment effect on the untreated (ATU) results indicated that the non-user's decision not to use appears to be irrational as they would have been better off in terms of yield and income if they chose to use. Farmers who did not used might be less informed about the importance of RWHTs uses as they reduced exposure to soil degradation by conserving soil moisture, increasing soil organic matter, reducing soil loss from erosion, flooding and reducing weeds.

	Income from the main crop in CFA						General Household Income in CFA				
Combination	**Treated characteristic (α1)**		**SE**	**Untreated Characteristic (α1)**	**SE**	**Impact Return**	**Treated characteristic**	**SE**	**Untreated characteristic**	**SE**	**Impact Return**
Zai pit only	Treated (X)	270 564	7353.80	295 514	10152.91	-24 950	458 685	17224.02	469 503	21439.97	-10 818
	Untreated (Y)	195 244	7785.80	262 480	10918.10	-67 236	229 646	14260.10	398 504	18332.36	-168 858
	Effects (ATT)	75 320***		ATU= 33 034***		42286	229 039 ***		70 999 ***		158040
Half-moon only	Treated	311 139	11709.88	360 007	8733.91	-48 868	554 346	26186.27	695 802	17981.30	-141 456
	Untreated	179 587	10076.84	244 528	7474.74	-64 941	183 947	17478.22	370 851	12622.51	-186 904
	Effect (ATT)	131 552***		ATU=115 479***		16073	370 399***		324 951***		45448
Zai pit-Half-moon combined	Treated	319 857	15284.24	367 617	7373.21	-47 760	635 364	34573.24	593 864	17796.44	41 500
	Untreated	97 756	18344.89	256 492	6945.77	-158 736	2 095	33564.75	392 309	12526.56	-390 214
	Effect (ATT)	222 102***		ATU=111 125***		110976	633 269***		201 554***		431714

Table 5: Effects of the use and non-use of RWHTs on household income estimated by ESR
*Notes: ***, indicates significance level at 1%; ATT=Average Treatment effect on the Treated; ATU= Average Treatment effect on the Untreated; CFA= Africa Francophone Community.*

4. Conclusion and Recommendations

The determinants of the choice of Zai pits and Half-moon technologies got more consideration among SWCTs as the major ways to reduce climate related shocks. Previous studies focused mostly on the agricultural technologies' adoption, leaving out information on simultaneous uses ofZai pits and Half-moon technologies and its effects on income. This study assessed the determinants of the choice of specific Zai pits and Half-moon technologies, which is followed by quantification of the effects of using these technologies on farmers' income.The result of the analysis revealed that the effects of main factors influencing smallholder farmers' choice for RWHTs were either separated or jointly on the two technologies. The distance to the nearest market, number of contacts with extension service providers, farm production assets, farmer's perception on soil erosion had positive effects on the choice of Zai pits while farm production assets, farmers' perception on soil erosion and their risk-attitude positively affected the choice for Half-moon. Using RWHTs increased both general household income and main crop income. The highest payoff is achieved when RWHTs are used jointly rather than separately.

The results of the study stipulate that there is a need for increasing farmers' perception towards the technologies for effective technology promotion to handle the soil degradation problems and reduce food insecurity in Kita district. This can be done through sensitization, training, increasing contact with extension service providers and access to inputs. Thereis also need to improve farmers' business-orientation behaviour such innovativeness, risk attitude and management skills in agriculture through improving their farming business skills and ability of climatic information analysis in terms of rainfall, timing and distribution.

5. Acknowledgement

I am thankful to Prof. Margaret Ngigi and Dr. Oscar Ingassia Ayuya at Egerton University for their highly input. I am grateful to Mahamadou S. KONTE at University of Segouand Dr. Macire KANTE at National Center for Scientific and Technological Research-Bamako Institute for Research and Development Studies for their useful supports. Their availability, guidance and support are highly appreciated.

6. References

i. Abdulai, A. and Huffman, W. (2014). The Adoption and Impact of Soil and Water Conservation Technology: An Endogenous Switching Regression Application. Land Economics, 90(1): 26-43.
ii. Akinwande, M. O., Dikko, H. G., and Samson, A. (2015). Variance inflation factor: As a condition for the inclusion of suppressor variable (s) in regression analysis. Open Journal of Statistics, 5(07), 754.

iii. Aubert, B. A., Schroeder, A., and Grimaudo, J. (2012). IT as Enabler of Sustainable Farming: An Empirical Analysis of Farmers' Adoption Decision of Precision Agriculture Technology. Decisions Support Systems, 54(1), 510-520

iv. Ayande, A., Radeny, M., Morton, J.F., and Muchaba, T. (2018). Rainfall Variability and Drought Characteristics in Two Agro-Climatic Zones: An Assessment of Climate Change Challenges in Africa. Science of the Total Environment, 630, 728-737.

v. Blaikie, P. and Brookfield, H. (2015). Land Degradation and Society. Routledge Revivals. 711 Third Avenue, New York, NY 10017.

vi. Bourguignon, F., Fournier, M. and Gurgand, M. (2007). Selection Bias Corrections Based on the Multinomial Logit Model: Monte Carlo Comparisons. Journal of Economic Surveys, 21(1), 174-205.

vii. Cooper, P. J. M., and Coe, R. (2011). Assessing and Addressing Climate-Induced Risk in Sub-Saharan Rainfed Agriculture: Foreword to a Special Issue of Experimental

viii. Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T. and Yusuf, M. (2009). Determinants of Farmers' Choice of Adaptation Methods to Climate Change in the Nile Basin of Ethiopia. Global Environmental Change, 19(2):248-255.

ix. Di Falco, S., Marcella V., and Mahmud Y. (2011). "Does Adaptation to Climate Change Provide Food Security? A Micro-perspective from Ethiopia." American Journal of Agricultural Economics 93 (3): 829–46.

x. Duncan, D. S. (2016). Linking Soil Microbiology and Environmental Conditions to Variability in Nitrous Oxide Production in Bioenergy Systems. The University of Wisconsin-Madison

xi. Hellmuth, M. E., Osgood, D. E., Hess, U., Moorhead, A., and Bhojwani, H. (2009). Index insurance and climate risk: Prospects for development and disaster management. International Research Institute for Climate and Society (IRI).

xii. Kamakura, W., A. (1989). The Estimation of Multinomial Probit Models: A New Calibration Algorithm. Transportation Science 23, 253-265

xiii. Kassie, M., Jaleta M., Shiferaw, B., Mmbando, F., and Mekuria, M. (2013). Adoption of Interrelated Sustainable Agricultural in Smallholder Systems: Evidence from Rural Tanzania. Technological Forecasting and Social Change, 80,525-540.

xiv. Kariyasa, K., and Dewi, Y., A. (2013). Analysis of Factors Affecting Adoption of Integrated Crop Management Farmer Field School (icm-ffs) in Swampy Areas. International Journal of Food and Agricultural Economics, 1(2), 29-38.

xv. Kersting, S., and Wollni, M. (2012). New Institutional Arrangements and Standard Adoption: Evidence from Small-Scale Fruit and Vegetable Farmers in Thailand. Food Policy, 37(4), 452-462.

xvi. Larson, D., F., Otsuka, K., Matsumoto, T., and Kilic, T. (2014). Should African Rural Development Strategies Depend on Smallholder Farms? An Exploration of the Inverse Productivity Hypothesis. Agricultural Economics, 45(3), 355-367.

xvii. Manda, J., Alene, A., D., Gardebroek, C., Kassie, M., and Tembo, G. (2016). Adoption and Impacts of Sustainable Agricultural Practices on Maize Yields and Incomes: Evidence from Rural Zambia. Journal of Agricultural Economics, 67(1), 130-153.

xviii. McFadden, D. (1973) Conditional Logit Analysis of Qualitative Choice Behavior in P. Zarembka (Ed.), Frontiers in Econometrics, New York: Academic Press, 105–142.

xix. Mango, N., Makate, C., Tamene, L., Mponela, P., and Ndengu, G. (2017). Awareness and Adoption of Land, Soil and Water Conservation Practices in the Chinyanja Triangle, Southern Africa. International Soil and Water Conservation Research, 5(2), 122-129

xx. Mansur, E., T., Mendelsohn, R., and Morrison, W. (2007), Climate Change Adaptation: A Study of Fuel Choice and Consumption in the US Energy Sector. Journal of environmental economics and management, 55 (2008): 175-1993

xxi. Muna, M., M., Waswa, F., and Mairura, F. S. (2017). Socio-economic Factors Influencing Utilisation of Rain Water Harvesting and Saving Technologies in Tharaka South, Eastern Kenya. Agricultural Water Management, 194, 150-159.

xxii. Sangho, H.; Traore, M.G.; Joos, O.; Keita, H. D.; Keita, A.S. and Munos, M. K. (2015). Recherche Formative sur L'enregistrement D'événements Vitaux en Milieu Communautaire au Mali. Santé Publique, 27(4), 565-574.

xxiii. Teklewold, H., Kassie, M., Shiferaw, B. and Kohlin, G. (2013). Cropping System Diversification, Conservation Tillage and Modern Seed Adoption in Ethiopia: Impacts of Household Income, Agrochemical Use and Demand for Labor. Ecological Economics, 93, 85-93. World Bank.(2015) Country Overview, Mali.Retrieved from http://www.worldbank.org/en/country/mali/overview. On July 22nd 2018.

xxiv. Yosef, B. A. and asmamaw, D. K. (2015). Rainwater Harvesting: An Option for Dry Land Agriculture in Arid and Semi-Arid Ethiopia. International Journal of Water Resources and Environmental Engineering, 7(785):17-28.

Appendix

Variables	Items	Factors Loadings	CR	AVE
Attitudinal and perception constructs				
Perception of timeliness [Kassie *et al*., 2013]	Rainfall comes and stops on time	0.868	0.646	0.592
	There was adequate rain for the crops during the last five years	0.452		
	Throughout the growth period of the crops, the rain was well distributed in the last three years	0.906		
Risk-taking attribute [Kassie *et al*., 2013]	I like to devote my assets and my time to agricultural technology with high profitability	0.788	0.687	0.621
	I prefer agricultural technology with less risky outcomes	0.876		
	If the technology is highly risky and high profitable, I would go for profit but with insight into the risk	0.690		
Level of trust in institution [Kassam *et al.,* 2014]	I trust the agricultural associations as they work for the welfare of the farmers and the sectors	0.892	0.737	0.565
	I trust the local agricultural officer	0.899		
	I trust the public institution (local government)	0.662		
	I trust the NGO' officers	0.466		
Perceived technological attributes				
Compatibility [Rogers, 2010]	Using the RWH technologies is compatible with most aspects of my work	0.906	0.898	0.832
	Using RWH technologies fits my work style	0.931		
	Using RWH technologies fits as well with the way I like to work	0.899		
Perceived technological attributes				
Ease of use [Aubert *et al*., 2012]	I clearly understand how to use RWH technologies	0.679	0.614	0.483
	Learning to operate RWH technologies system is easy for me	0.857		
	I find RWH technologies inflexible to interact with	0.462		
	It is easy to perform work using RWH technologies	0.722		
Users' innovativeness [Aubert *et al*., 2012]	I am very curious about how things work	0.786	0.797	0.626
	I like to experiment with new ways of doing things	0.841		
	I like to take a chance	0.884		
	I like to be around unconventional people who dare to try new things	0.631		
Ressources availability [Aubert *et al*., 2012]	I have the resources, opportunities and knowledge for using RWH technologies	0.852	0.716	0.641
	I will be able to use RWH technologies if I wanted	0.805		
	There are no barriers to me using RWH technology	0.741		

Table 6: Factor Analysis of Attitudinal, Perception Constructs and Technological Attribute
Note: CR and AVE Denote Composite Reliability and Average Variance Extracted, Respectively