International Institute of Tropical Agriculture

Effects of Farm Household Heterogeneity on Agricultural inputs Adoption in Rwanda

By

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Declaration

I declare that this dissertation is the result of my own work and has not submitted for any other degree at university of Rwanda or any other institution

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Dedication

This dissertation is dedicated to the family of NDANDALI Alex and to the memory of my brother HAGENIMANA TWAHIRWA.

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Abstract

This study aims to assess the farm household-based factors that affect adoption of agricultural inputs (e.g. inorganic and organic fertilizers, travertine, and improved seeds). The adoption of agricultural inputs for improving crop yields and food security is still limited in many developing countries, including in Rwanda. Soil nutrients outflow go beyond inflow which create negative nutrients balance that affect productivity and call upon inputs use. One size fits all approaches have been used to deliver agricultural technology but famer's diversity undermine the adoption. This study was conducted in Southern, Eastern and Western provinces of Rwanda. Two-stage cluster sampling technique was performed to select respondents; 15 cells were randomly selected in each district within 17districts. Descriptive statistics, logistic regression, and correlation analysis were performed via STATA. Regression results reveal that farm types, irrigation use, and agricultural training have highly significant effects at (p=0.01) and have positive relationships with inorganic fertilizers adoption as well as access to credit, farm labor and cropping system have affected significantly at (p=0.05) but cropping system such as intercropping and farm labor have negative relationships. Moreover, farm types have positive relationships and have no statistical significant effect on the adoption of travertine while agro ecological zone, agricultural training and access to credit have significant effects at (p=0.05). Farm types, agroforestry practices, agricultural training, irrigation practices have positive relationships and affect highly significant at (p=0.01) the adoption of improved seeds. Furthermore, land slope characteristic have positive relationships and affect significantly at (p=0.05) whereas cropping systems like intercropping have negative relationships and affect significantly adoption of improved seeds. Results indicated that access to credit, agricultural training, irrigation practices and cropping systems (monocropping) was the most driving factors for agricultural inputs adoption in the study areas. Farm typologies captured a defined association between agricultural inputs adoption and farm types. Therefore, the current farm typologies should be applied nationally and support programmes tailored to them. In addition strengthening subsidy program to small farmers by promoting irrigation and agroforestry practices are recommended.. It is highly recommended for further researchers to analysis the role of crop index based insurance on agricultural inputs adoption.

Keywords: *Agricultural inputs, farm household heterogeneity and technology adoption*

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Abbreviation and acronyms

DAP: Diammonium Phosphate

EICV: Enquête Intégrale sur les Conditions de Vie des Ménages, called, in English, Integrated Household Living Condition Survey.

IITA: International institute of tropical agriculture

IMPROSADOPT: Improved seeds adoption

INORGAFERADOPT: Inorganic fertilizers adoption

Kg: Kilogram

MINAGRI: Ministry of Agriculture and Animal Resources

NGO: Non Government Organization

NISR: National Institute of Statistic of Rwanda

NPK: Nitrogen, Phosphorus and Potassium

PCR: Principal component analysis

RGER: Rwanda government's state of environment report

RHoMIS : Rural Household Multi-Indicator Survey

TRAVADOPT: Travertine adoption

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CHAPTER ONE: GENERAL INRODUCTION

1.1. Background of study

The adoption of demonstrated agricultural technologies in developing countries is the important aspects to poverty reduction, food security and improved farmer's livelihoods in rural areas (Berhun *et al*., 2014).The implementation of agriculture technologies such as exemplified by the green revolution has shown a considerable impact on agricultural productivity in many Asian countries (Otsuka and Kalirajan,2006).The imitations of the Asian green revolution in sub-Saharan countries are the foundation to increasing agricultural productivity in African countries where agriculture is dominated by subsistence farming (Mitchel,2008).However, the adoption level of agricultural technologies at small scale farming system differs among farmers and mainly accounted to agricultural inputs access, labor availability, and ability to manage the changes on soil quality (Frossard and Vlek, 2014).Furthermore, asymmetric information, risk management, infrastructure and resource endowment explain the extent of agricultural innovation adoption (Foster and Rosenzweig., 1996). Several studies have been conducted on agricultural inputs adoption although few of them paying attention on farmer diversity.

The impacts of farm household diversity on agricultural productivity, food security resilience, farmer income and countryside progress remain inconclusive (Dimitris, 2015).In Rwanda, agriculture is dominated by small farm holders, subsistence and rain-fed agriculture relying on conventional technologies and practices which make the sector vulnerable to rainfall variability. Around 96 per cent of rural households depend directly or indirectly on agriculture for their well being (Ministry of agriculture and animal resources [Minagri], 2018). Long subsistence farming in Rwanda face a complex set of challenges such as to limited access to finance, insurance, technology, agricultural mechanization, improved seeds, chemical fertilizers as results the crops yield is always below expected potential and food security and nutrition remain a major concern at household level (Minagri, 2018).

The government of Rwanda has adopted several measures including use of improved seed and inorganic fertilizers, promotion of land use consolidation, crop intensification programs and soil management strategies in order to improve agricultural production. Unfortunately, the inputs consumption level still low and it has been planned to be 39kg/ha on fertilizers use and 75% of farmers are expected to use improved seed in 2024 (Minagri 2018).

Private projects have also been implemented to encourage the use of different agricultural technologies to diverse farming systems. However, farm household based factors that limit the adoption of agricultural technology are still limited in Rwanda and are linked to farmer's diversity (Bidogeza *et al.*, 2009; Niyitanga *et al.*, 2015).

Furthermore, weak understanding of farm household heterogeneity in context of resource endowment, objective, production goals and consumption decisions, level of education, farm management skills, past experience and attitude to risk are often a hindrance to the design, targeting, implementation and scaling out of agricultural development projects (Tittonel *et al.*, 2010). Thus, understanding farm household heterogeneity is imperative to address the low productivity among smaller farmers that are associated to ineffective and inefficient adoption of agricultural technology intervention. Several researches revealed that targeting agricultural technology interventions can potentially contribute to improved crop productivity, food security and farmer's livelihood sustainability in rural areas.

1.2. Problem statement

The adoption of agricultural technology intervention towards poor productivity problems due to land degradation is individual and spatial heterogeneous at small scale farms (Tithonel *et al.*, 2010). Soil fertility decline and degradation are the main challenges in sub-Saharan Africa countries leading to agricultural productivity crisis. Stoorvogel and Smaling (1990) indicated that average of 660 kg N ha^{-1}, 75 kg P ha and 450 kg K ha^{-1} have been lost in 37 countries of Sub-Saharan Africa including Rwanda. This is equivalent to 1.4 t of urea ha^{-1}, 375 kg of triple superphosphate (TSP**)** ha^{-1} or 0.9 t of phosphate rock (PR) ha^{-1} and 896 kg of potassium chloride (KCl) ha^{-1}. Previous study revealed that soil loss in Rwanda is governed by water erosion and varies from 41.5 to 100 tones/ha depending on slope strength and land use in highland region (Kagabo et al., 2012). The average annual soil loss in the entire country was estimated at 1642 t/ha (Karamage *et al*., 2016).

The loss of macronutrient (K,P) and Mg was the most limiting factor that contribute to 55.3% and 35% yield gap in Kibungo and Rubona site respectively (Ndabamenye *et al.*2013). In addition, soil acidity affects crop yield by reducing available soil nutrients and restricts root growth and access to water which make land less productive (Nduwumuremyi *et al*., 2013).

About three-quarters of Rwanda's soils are acidic, with a pH below 5.5 inducing a deficiency to nitrogen and phosphorus (Rwanda government's state of environment report [RGER], 2015).Several programs such as soil conservation, land husbandry and crop intensification were initiated and the main goal for these programs was to increase production of six food crop priority including maize and beans and ensure food security by supplying of inputs (fertilizers and improved seed) in different agro ecological zones (Bucagu *et al*,.2014).Despite the efforts and roles of others various institutions towards agricultural technologies implementation there is still low adoption among smallholder farmer. As result, 20% of Rwandan household were food insecure (NISR, 2015).Reports suggest that 39% of rural households are under poverty line and it is expected to be 17% in 2024([NISR, EICV], 2018). Some studies have been conducted on adoption determinants but few focused on farm household based factors (Nigussie *et al.,* 2017). Ignoring farm household factors is often a hindrance and a failure for adoption of new agricultural technology. Recently, one size fits all approaches have been used for agricultural inputs delivery and consequently it is unsuccessful and ineffective at farm household level (Toan, O'Keefe and Craze, 2016). Furthermore, recognizing as well as understanding farm household heterogeneity remains important aspects to support decision and policy making. Therefore, this research intended to assess farm household-based factors affecting agricultural inputs adoption in Rwanda with geographical coverage areas of seventeen districts of Rwanda located in Western, Eastern and South province.

1.3. General objective

The main objective was to understand and exploit farm household heterogeneity effects on agricultural inputs adoption in Rwanda.

1.3.1. Specific objective

To assess farm household based factors affecting agricultural inputs adoption in Rwanda

1.4. Research questions

1. How farm household based factors affect adoption of organic and inorganic fertilizers in Rwanda?
2. How farm household based factors affect adoption of travertine in Rwanda?
3. How farm household based factors affect adoption of improved seeds in Rwanda?

1.5. The significance of this study

Agricultural inputs use could be improved by identifying farmers heterogeneity factors and the revelation of farm household factors may guide to find solutions to the problem of food security and nutrition that are important areas to which agriculture can accelerate its efforts because 20% of Rwandan households are food insecure (NISR, 2015).Identifying farm household based factors can helps in designing policies that facilitate poor famers via better implementation of agricultural innovation. The impact evaluation of agricultural intervention in rural areas which are subjugated by small farm holders, subsistence and rain-fed agriculture, relying on conventional technologies and practices and complex diversity of farmer may be effective at all levels.

Dealing with low understanding of factors affect adoption reflects to the impact of farm household heterogeneity in agriculture and rural development along different landscape which is still a debate in recent studies while the adoption of new agricultural technology is a crucial constraint within different farmers. The findings of this study may help to locate different interventions that have met obstacles to strengthen agriculture in rural development due to weak identification of household.

CHAPTER TWO: LITERATURE REVIEW

2.1. Farm typology

Farm typology is a quantitative or qualitative classification of farm household in homogenous groups which have common production constraints and motivation (Petrus , 2013).Farm typology have been developed to differentiate the main farm types based on their characteristics such as land ownership, resources endowment, production orientation, land size and livestock (Renske *et al.,*2013).Empirical evidence from recent researches confirms a household heterogeneity impact in new agricultural technology based on socio-economic and biophysical factors. However, in Rwanda new agricultural technologies have not been fully adopted due to non-homogenous of farm household (Bidogeza *et al*, 2009).

Size of farms and resource endowment have shown a constructive relationships with adoption of new agricultural technologies whereas the intangible characteristic such as willingness to experiment the new technology impairs the adoption and many small farmers choose to wait for the outcome of adopted technology implemented by the neighbors. Land ownership has important contribution while proposing any innovation such as perennial or seasonal cropping systems. This is because cropping calendar depends on how long farmer has tenure agreement either temporal or permanent across landscape, education level, family composition and wealth class determine the difference in adoption any innovation (Kebede, 2007). Kamanga (2011) reported that farmers expect new agricultural technology to increase food availability and nutrition security even though the optimization benefits may depend on resources used.

2.2. Farm typology development

Different method have been developed for farm household typology construction such as Step by step comparison of land performance involving member of family, farming experience and production orientation.). The experts consider the typology construction by grouping farms into cluster defined by key informant and local expert using participatory rankings (Giller *et al.*, 2011).The visible possessions are significant when ranking is based on wealth status (Kebede, 2007).The adoption of agricultural innovation which is more profitable is interrupted by socioeconomic and biophysical factors and this varies among different farm households..

2.3 Determinants for soil management practices adoption

Soil management decision relies on different factors including biophysical and socioeconomic factors such as slope which determine land use system and farmer characteristics are the most factors enhancing decisions among farmers (Rajendra and Nalina, 2009).Population growth dramatically affects the cultivated land and farmer shifts towards different positions of landscape including steep slope in turn provoke soil erosion. The effect of soil erosion such as loss of crop yield and food insecurity pushes farmers to adopt different soil management strategies at community level and individual farm level. However famers' management skills on their resource different from one to another across sites in terms of resources endowment, farm size, availability and accessibility to different inputs (Dunjana *et al.,* 2018).Kamanga (2011) reported that asset owned by farmer determined the use of mineral fertilizers and manure application.

2.4. Determinants factors for agricultural technology adoption

According to Saguye (2017) factors affecting agricultural technology adoption are classified and summarized in the following tables

Determinants factors	**Components**
1.Demographic factor	Age, Household types ,Educational level ,Gender and Family labor
2.Institutional factors	Land tenure, Training and access to credit
3.Biophysical factors	Land slope ,Farm size and region
4.Economic factors	Off farm income and Livestock owner
5.Attitudes factors	Perception extend

Table 1: Representation of determinants factors of agricultural technology adoption

Marian (2017) reported that land size, access to information, land tenure and household head's age have positive relationships and significantly predict the adoption of best management practices

2.5. Theoretical and conceptual framework

2.5.1. Theoretical framework

The adoption models have been developed and there is no independent model to explain the factors of agricultural technology adoption including socioeconomic, environmental and individual perception on the intervention (Thangata and Alavalapati, 2003).

To understand farm typology different theories have been developed to explain various factors determining individual farmer behavior as results of external and internal factors interaction (Roger, 2003). These theories comprise Farming context, Agro ecological zones and adoption theory.

i. Theory of farming context

The theory aims to assess the differences that exist in farming practices within a given farm types and suggest that decision on farming systems rely on biophysical, socioeconomic and personal factors (Kaine and Lee, 1994)

ii. Agro ecological zone

Esther et al., (2016) reported that agro ecological zone capture the biophysical and climatic environment in which agriculture is heavily dependent. Farmers have the same constraints and opportunities to adopt agricultural technology practices and their socio economic characteristics, resource availability, physical characteristics of the land and different interventions provided by public or NGO sectors determine the adoption level. (Paudel and Thapa, 2004).

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iii. Adoption theory

The adoption of agricultural technology is integration of any innovation to the existing farming practices within a period of time where individual decide to use the new innovation based on information received and the potentiality of innovation. The innovation diffusion approach, perception, adoption and economic constraint approaches have been used to explain the adoption paradigms. (Feder and Zilberman ,1985).

2.5.2. Conceptual framework

The conceptual framework model presents the empirical linkage connecting independent variable "Farmers characteristics, biophysical and socioeconomic factors" and dependent variable "agricultural inputs adoption".

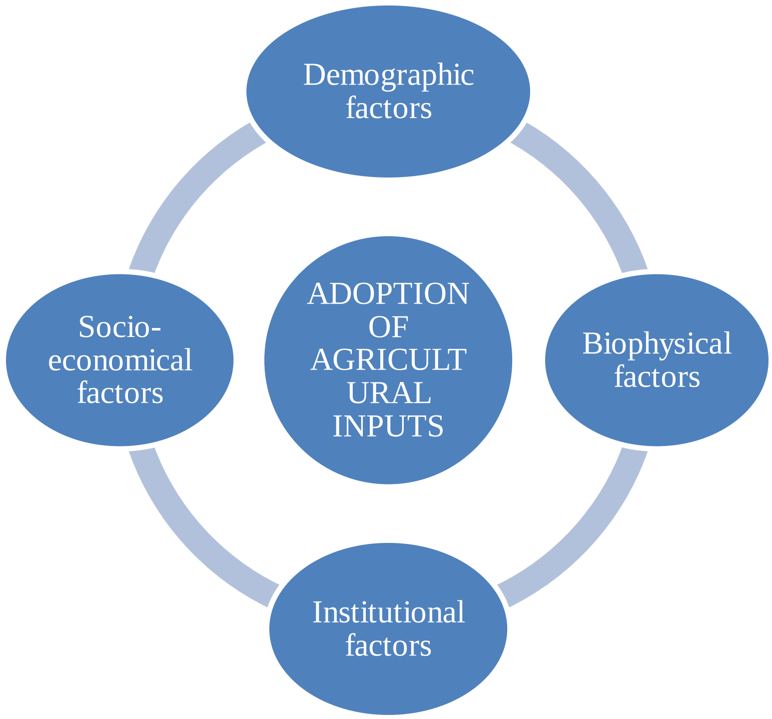


Figure 1: ***Conceptual framework***

With reference to current review of literature, the following hypothesis were formulated in regards to the working variables on the adoption of agricultural inputs

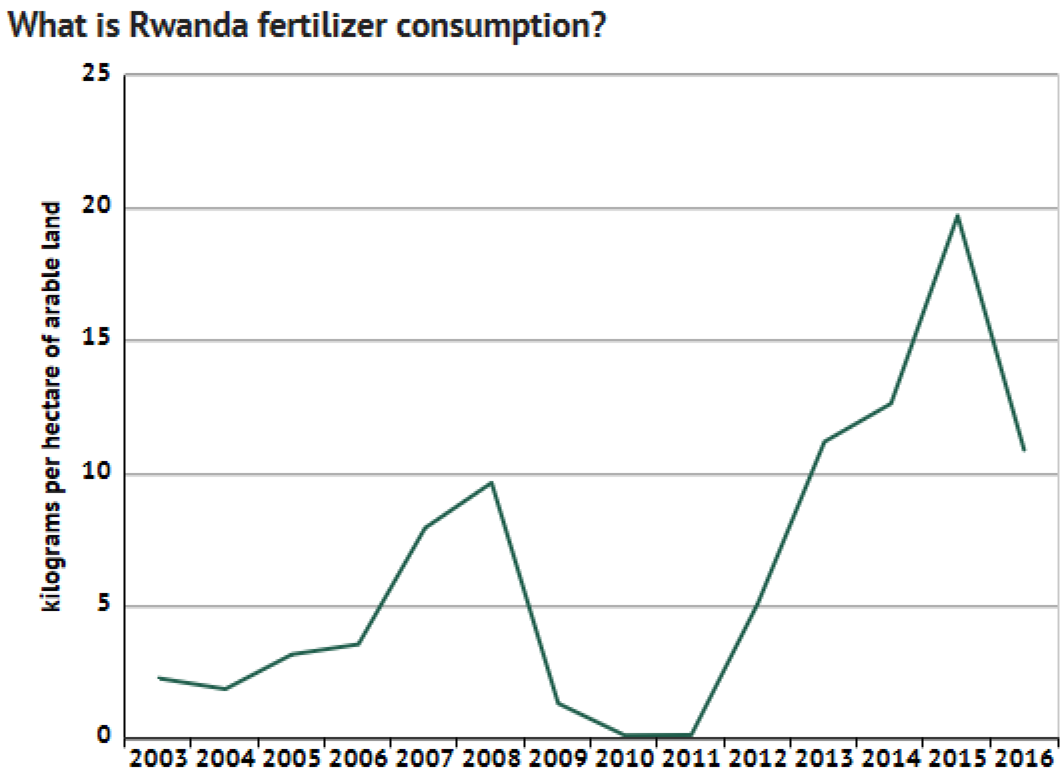
Agricultural Inputs use (Fertilizers ,improved seed and travertine)	**A. Farm Household characteristics**	**Hypothesis**
	Gender	±
	Age	±
	Off income	+
	Household types	+
	Education level	+
	Livestock owner (TLU)	+
	Farm size	±
	land tenure	+
	Access to credit	+
	Farm history	+
	Agricultural training	+
	B. Biophysical factors	
	Land slope	+
	Agro ecological zone (Region)	±
	C. Soil management practices	
	Agroforesrty	±
	Irrigation	+
	Intercropping	+
	D. Perception on agricultural inputs	+

The Sign +, - and ± Stand for positive relation and negative relation between dependent and independents variables under this study

Table 2: Representation of variable under study and their hypothetical perspectives

2.5.3. Fertilizer consumption in Rwanda

In 2016, the level of fertilizers use in Rwanda was 10.9kg per ha whereas in previous year of 2015 was 19.7 kg per ha which decreased at 44.91%.



Source: KNOEMA, (2019)

Figure 2: Representation of Rwanda fertilizers consumption

2.5.4. Historic fertilizer use in Rwanda

The use of inorganic fertilizers started in 1970s after detecting soil fertility depletion. The most common fertilizers used in Rwanda include NPK, DAP, Urea with different labels. The government of Rwanda launched strategic plan for agriculture transformation focused on erosion control, application of inputs, improved seed. The fertilizers consumption has increased from 6 to 30 kg/ha from 2006 to 2010 respectively (Minagri, 2018).

CHAPTER THREE.MATERIALS AND METHODS

3.1 SITE DESCRIPTION

This study was conducted in different agro-ecological zones of Rwanda mainly Eastern province (Eastern savanna), Western province (Congo-Nile watershed divider) and South province (central plateau).Eastern province is dominated by plateau with elevation of 1200-1500 m.s.l with rain fall between 800 to1000 mm per year. In this area, the dominant soil is Ferralsols and the slope ranges from 13-55%. The dominant farming systems are characterized by banana, cassava, maize and bush beans and livestock are dominated by cattle and goats. The western province is characterized by high land with steppe slope with high annual rainfall around 1400 to 2000mm and the temperature ranges from 15 to 16^{o}c. In the upland the dominant soils are Leptosol, Nitisol and Cambisol whereas in the lowland the dominant soils are Vertisols and Histosols. Western highlands are characterized by high soil erosion washing away soil nutrient content and increase soil acidity. South province is dominated by central plateau the annual rain fall is 1200mm and the annual temperature is 19^{0}C while the dominant soil are Acrisols,Leptosols and Cambisols in upland. Cassava, maize and intercropped banana and bean and different vegetable are dominant in home field.

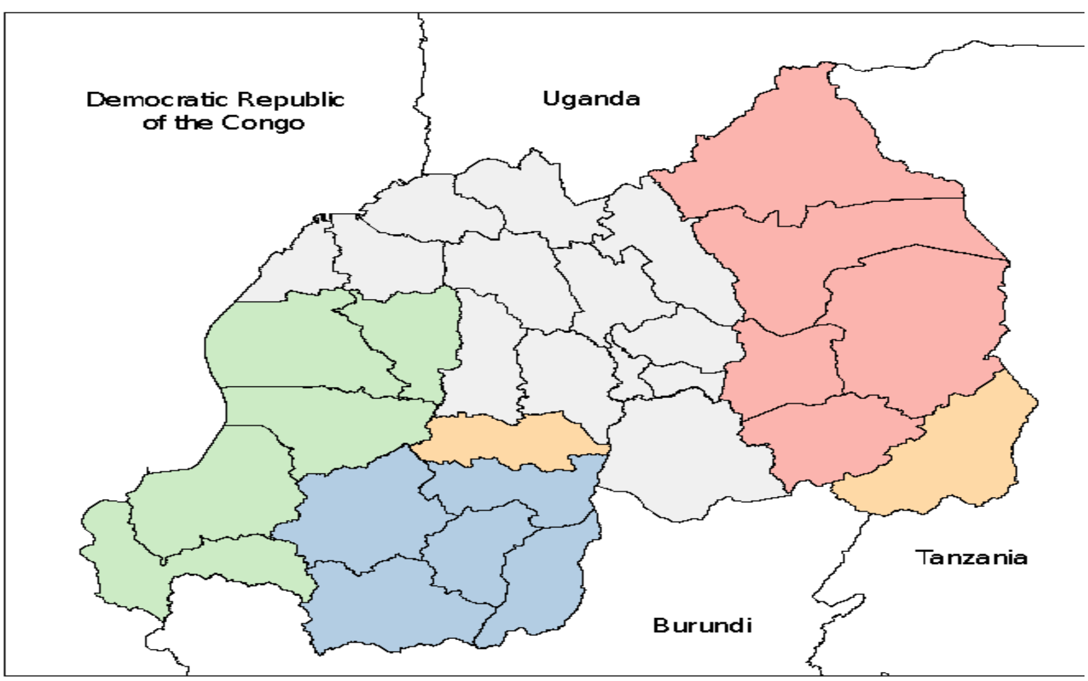


Figure 3: Illustration of study site .Source: Hammond et al. forthcoming

3.2. Sampling design

Two-stage cluster sampling was used to select respondents; 15 cells in each district were randomly selected. Following cell selection, farm households were identified through a quasi-random process next the centre of each village and random generated cardinal direction and random number to guide to visit the nth house in the specified direction.

3.3. Methods

The subsamples were taken from a sample size of 2703 interviewed farm households to a population size of 250,000 farming families in Rwanda under One Acre Fund in three province and seventeen districts to represent rural people in Rwanda using Rural Household Multi-Indicator Survey (RHoMIS).The sample size was used to develop ten farm types by combining different variables from different sources such as review of literature, principal component analysis (PCA), by performing a series of regression model and finally from cluster analysis (Hammond et al. forthcoming) .The difference of farm types came from crop productivity, access to information, livestock ownership, education level, wealth, opinion to input efficacy, use of input and land area

The following diagram below summarize the methodology used to select subsamples in this study

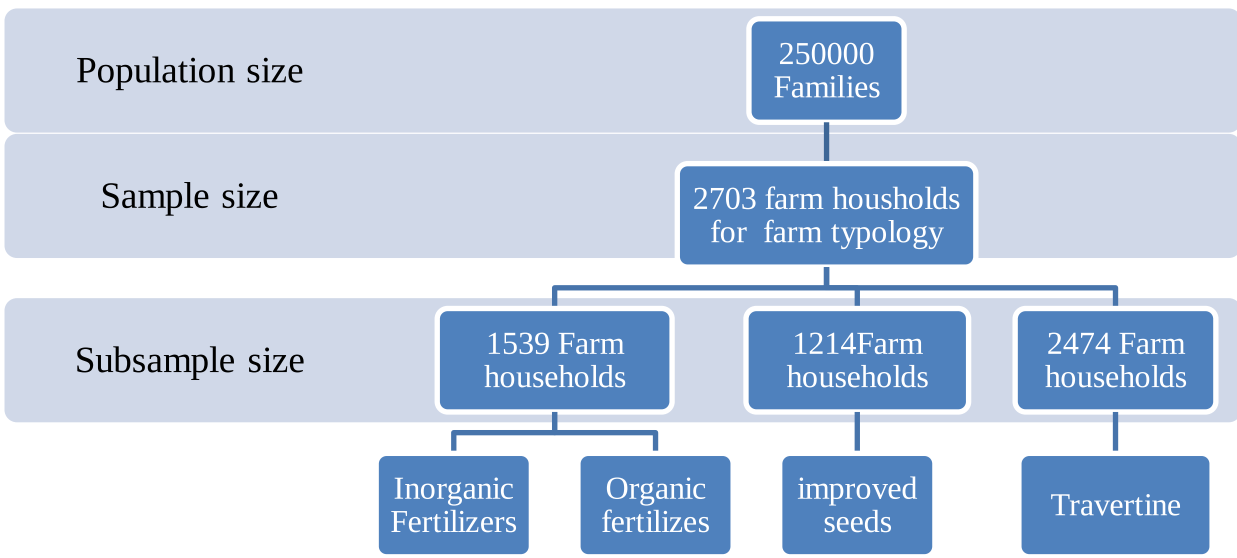


Figure 4 : Representation of subsamples selection approach

4. DATA ANALYSIS

Quantitative and Qualitative data were tabulated and cross tabulated via STATA. Descriptive statistic and logistic regression analysis were performed to assess farm household-based factors such as demographic, socioeconomics, institutional and biophysical factors affecting agricultural inputs adoption namely inorganic and organic fertilizers, improved seeds and travertine. The analysis was performed at a confidence interval of 95% probability (Z value between –1.96 and 1.96 and at least significance of 5%).

4.1 **Data processing**

The data were sorted, edited, coded and tabulated for analysis. During those processes, the data were transformed into meaningful information for easy interpretation and understanding.

4.2 Theoretical model and specification

Farm households were considered as adopters of agricultural inputs if they used organic or chemical fertilizers, travertine or sowed improved seeds either together or independently. The outcomes were dichotomous 1 for adopters and 0 for none adopters. The logit econometric model was used to determine the probability to adopt agricultural inputs under study. This model not only helps to evaluate different factors but also to estimate likelihood to adopt agricultural inputs

$$Y = \begin{cases} 1, & \acute{Y}_i \geq 0 \\ 0, & \acute{Y}_i \leq 0 \end{cases}$$

Y was equal to 1 for adopters and equally to zero for none adopters

The logit model became $Y = \beta 0 + \beta nXn + \epsilon$ where $\beta 0$: Intercepts and $\beta 1 \ldots \beta n$ stand for coefficients of explanatory variables and ϵ i.e normal distribution of error terms .The Logit models become

INORGAFERADOPT, IMPROSADOPT and TRAVADOPT : $\beta 0 + \beta 1$ Gen $+\beta 2$ Age $+ \beta 3$ Educ $+ \beta 4$ Farmsz $+ \beta 5$ Offfarm $+\beta 6$ Irrig $+ \beta 7$ Landown $+ \beta 8$Credit $+ \beta 9$ Landslp$+ \beta 10$ Tlu $+ \beta 11$Hhtype $+ \beta 12$ AFs$+ \beta 13$Intercrp$+ \beta 14$Aez$+ \epsilon$

CHAPITER FOUR: RESULTS AND DISCUSSIONS

This chapter highlights the results on the main farm household based factors that affect the adoption of agricultural inputs. The findings are represented in different sections including demographic factors, institution factors, biophysical factors and socioeconomic factors of farm households and some soil management practices.

4.1. Results interpretation

4.1. 1. Demographic characterisation of farm households

4.1.1 1.Age and gender of farm household

The table below indicates that the mean age was 42.57 and 34.79 years for females and males whereas 59.78 % and 40.22% of respondents were females and males respectively for fertilizers adoption aspect . Also the mean age for females and males was 42.57 and 34.43 years while 60.13 % and 39.87% were females and males respectively for improved seed adoption. For travertine the mean age was 42.64 and 35.27 years while 59,09 %and 40.9% were females and males respectively.This implies that Rwandan agricultural sector is dominated by females at a factor of 1.47times compare to males and older farmers than youths .The results shows that gender inequality is dominant and this makes agriculture sector stagnant therefore this call upon to promote and sensitizing gender equity to enhance sustainable agriculture development. Youth is less involving in agriculture because the sector is still subsistence and not taken as business, negative perception on farming activity and low access to credit. There is needed to integrate youth in agriculture sector as youth have innovative ideas and they are active to work. The results is supported by kristen (2016) found that gender imbalace in Rwanda agriculture sector is obvious . In his study, he reported that 82% of labors are female and also females represent 70% of active labour.

Agricultural Inputs		**Mean Age of respondents**	**Gender in %**	**n**
Fertilizers	Female	42.57	59.78	1539
	Male	34.79	40.22	
Improved seeds	Female	42.56	60.13	1214
	Male	34.43	39.87	
Travertine	Female	42.64	59.09	2474
	Male	35.27	40.91	

Table 3.Representation of ages and gender of respondents

4.1.1.2 Educational level

The results in the table below indicates that many households asked were uneducated and this counts to 6.56% of the respondents. Among other respondents 0.13%, 0%, 2.08% and 0.13% attended adult, post-secondary, primary and secondary education respectively and all these respondents never used any type of fertilizers. On contrary 55.56 %, 0.56%, 0.39%31.32 % and 2.34 % of respondents never attended school, adult education, post-secondary, primary and secondary respectively and have adopted fertilizers.

In addition 8.32% ,0.16%, 0%, 2.64 and 0.16 % of respondents was non users and never had access to school, adult education, post-secondary, primary and secondary respectively and did not use improved seeds whereas 54.56 %,0.62%, 0.39%,29.82% and 3.32 % of respondents never attended school, adult education, post-secondary, primary and secondary respectively and have adopted improved seeds.

Agricultural inputs	**No school**	**Adult education**	**Postsecondary**	**Primary**	**Secondary**	**N**
Control (no input)	101	2	0	32	2	1539
Percentage	**6.56**	**0.13**	**0**	**2.08**	**0.13**	
Organic Fertilizer	497	5	0	230	2	
Percentage	32.293697	0.32	0	14.94	0.13	
Inorganic Fertilizer	358	3	6	252	34	
Percentage	**23.26**	**0.19**	**0.39**	**16.37**	**2.21**	
Fertilizer use in %	**55.56**	**0.52**	**0.39**	**31.32**	**2.34**	
control	101	2	0	32	2	1214
percentage	**8.32**	**0.16**	**0.00**	**2.64**	**0.16**	
Improved seed	662	8	5	362	40	
percentage	**54.56**	**0.62**	**0.39**	**29.82**	**3.32**	

Table 4.Representation of farm household's educational level

Results indicates that 57.3% were uneducated, 1% attended adult education 0.3% attended post education, 32.7% attended primary and 3.1% attended secondary and did not adopt travertine .

The results revealed a strong need to increase farmers knowledge in agricultural activies including inputs use as the sector is dominated by uneducated and less educated farmhouseholds. education could increase access to information, farmer's analytical ability and understanding the use of agricultural inputs . The results is supported by Minagri (2018) acknowledged that farmal education level is low and 66 per cent of active labors had attended primary level education, 26 per cent had no education, 6.6 per cent attended secondary level education and only 1.4 per cent had attended tertiary level education. Asfaw and Admassie (2004) found that education is usually the only means to enhance the ability of farmers to acquire, synthesize and respond to innovations.

4.1.1.3. Farm types

Farm typologies were constructed based on farmer's difference in farming system including demographics, livelihoods, farm management and farm productivity combined with their difference in using modernized agricultural practices e.g. chemical fertilizers (NPK,DAP and Urea), travertine and improved seeds for maize and beans. Four stages were used for variables selection: literature review, principal component analysis, regression modeling, and cluster analysis. These variables were all gathered in the household survey. The outstanding variables were shortlisted using principal component analysis .Through exploration of different numbers of clusters, ten clusters 'farm types' were determined to provide the best balance of explanatory power and ease of interpretation and presentation (Hammond *et al*. forthcoming).

Farm types	Names of farm types	Farm types characteristic
1	Traditional, No Maize, Livestock focus	Less modernized agriculture, traditional practices , tuber crop and beans focus, low access to agriculture information and training
2	Traditional, No Maize	Focus on traditional crop, low livestock ownerships, low perception of the efficacy of inputs, low input use and very poor.
3	Marginal and unsupported	Poorest of all farm types, disconnection from sources of agricultural advice or training. single women with no education and very little land, low perception of input efficacy and low training or advice opportunities
4	Unsupported	Disconnection from agricultural advice and training but were not as marginalized in terms of physical assets or human capital,

5	Livestock with crops	Owned cattle, small land sizes, very prosperous. the majority of their incomes from livestock
6	Modernizing, uneducated	none any formal education,
7	Modernizing, educated, crops plus livestock	Household economy was based on a combination of crops and small livestock (chicken and goats)
8	Modernizing, educated, crops no livestock	Formal education , none livestock
9	Elite land owners	Land owners than the other types and more prosperous on income, food security, and livestock ownership
10	Cropping Champions	Very high crop sales, many positive plans, higher maize yields ,engage in agriculture training

Table 5. Representation of farm types characteristic

Results show that 1.62% ,0.91% ,2.08% ,0.91% ,0.13% 0% ,2.53%,0.39 %,0.13% and 0.19% of respondents were farm types 1,2,3,4,5,6,7,8,9 and 10 respectively and did not adopt any types of fertilizers whereas 5.65%, 9.16%, 5.98%, 4.88%,10.2%, 6.69%, 10.5%, 7.93%, 14.68 % and 14.7% of respondents were farm types 1,2,3,4,5,6,7,8,9 and 10 respectively and have adopted fertilizers . Moreover 2.06 %, 1.15%,2.64%,1.15%,0.16%, 0%,3.21%,0.49%,0.16% and 0.25% of respondents were farm types 1,2,3,4,5,6,7,8,9 and 10 respectively and did not adopted improved seeds while 0.33%, 0.41%, 6.92%, 8.81%, 6.26%, 9.47%, 16.1%, 14.42 % ,10.9 and 15.1% of respondents were farm types 1,2,3,4,5,6,7,8,9 and 10 respectively which have adopted improved seeds .Also the findings show that 6.83%, 6.91%. 11.64%, 12.65%, 6.47%, 7.52%, 15.51%, 8.57 %, 8 %, and 9.38% of respondents were farm types 1,2,3,4,5,6,7,8,9 and 10 respectively who did not adopt travertine but 0.12%, 0.24%, 0.40%, 0.69 %, 0.36%, 0.69 %, 0.57%, 0.49 %, 0.65% and 0.93 % of respondents were farm types 1,2,3,4,5,6,7,8,9 and 10 respectively and have adopted travertine (annex 5).

Inputs Use	1	2	3	4	5	6	7	8	9	10	n
Control	25	14	32	14	2	0	39	6	2	3	1539
Percentage	1.62	0.91	2.08	0.91	0.13	0	2.53	0.39	0.13	0.19	
Organic fertilizers	60	107	38	16	114	33	80	41	131	127	
Percentage	3.89	6.95	2.47	1.04	7.41	2.14	5.19	2.66	8.51	8.252	
Inorganic fertilizer	27	34	54	59	54	70	81	81	95	100	
Percentage	1.75	2.21	3.51	3.846	3.51	4.55	5.26	5.26	6.17	6.49	
Fertilizers use in %	**5.65**	**9.16**	**5.98**	**4.886**	**10.2**	**6.69**	**10.5**	**7.93**	**14,68**	**14.7**	
Control	25	14	32	14	2	0	39	6	2	3	1214
%	2.06	1.15	2.64	1.15	0.16	0.00	3.21	0.49	0.16	0.25	
Improved seed	4	5	84	107	76	115	195	175	133	183	
%	0.33	0.41	6.92	8.81	6.26	9.47	16.1	14.42	10.9	15.1	

Table 5.Representation of agricultural inputs adoption and farm types

The findings revealed that the adoption of agricultural inputs varied across farm types where farm households belong. The general trends on agricultural inputs use across farm types showed that more adopters were from farm types 10,9,8 and 7 because they were wealthier and low adopters were from farm types 1,2,3 and 4 because they were poorer. The differences in adoption were due to acces to agricultural information and training , formal education that increase farmers analytical ability on inputs use, land ownership and diversified sources of income . low access to agriculture information and training low livestock ownerships, low perception of the efficacy of inputs and lack of physical asset made farm types 1,2,3,and 4 less adopters .The results are in line with Marian (2017) who asserted that farm households have distinct perception and internal motivation across style and farm types which deterimine the rate of adoption .

4.1.2. Institutional factors

4.1.2.1 Land tenure

The results show that 29.43%, 12.28 % and 18.12 % of respondents had own land in rent and did not adopt the use of organic, inorganic fertilizers and improved seed respectively. although 11.57 % , 28.72 % and 18.12 % of respondents had owner land in rent and adopted organic ,inorganic fertilizers and improved seed.

Also it shows that 23.39% ,18.91% and 25.62 % of respondents had own land and did not adopt organic, inorganic fertilizers and improved seed respectively whereas 16.05%, 20.53% and 12.27

% had own land and have adopted organic, inorganic fertilizers and improved seed respectively. On the other hand 6.17%, 5.98% and 7.91 % of respondents had rent in land and did not adopt organic, inorganic fertilizers and improved seed respectively while 4.35%, 4.55% and 2.97% had rent in land and adopted organic, inorganic fertilizers and improved seed respectively (annex 6). For travertine adoption there were 38.20%, 37.39% 0.08% and 10.67% of respondents whohad ownland rentin land , own land and ownland rentout-communal land and rent in land respectively and did not adopt the use of travertine also it shows that 2.75%,1.70% ,0% and 0.28%of respendents had ownland rentin land , own land and ownland rentout-communal land and rent in land respectively and have adopted the use of travertine (annex 7). The results indicated that land tenure have affected positively the adoption of travertine use in the study areas. Land tenure affect the adoption because farmers expect the effect of added organic materials after a given period because organic fertilizers are slow releasing of plant nutrients and its application in one season reflect its use in next season this imply that without land tenure farmers are reluctant to invest in agricultural technology. In addition organic fertilizers application has residual effects which determine the longevity of organic amendment types (Demelash *et al.,* 2014).Similar results were found by Goswami (2015) reported that land ownership increase inputs use intensities and adoption of productive practices by farmers.

4.1.2.2 Access to credit

The table below shows that 6.04 %, 7.66 % of respondents were none adopters of any types of fertilizers and improved seeds respectively while they had no access to credit but 57.57% and 54.58 % of of respondents have adopted fetilizers and improved seed respectively but they did not have access to credit whereas 2.86 % and 3.62% of respondents were none adopters of fertilizers and improved seeds while they had access to credit but 33.45% and 34.13% of respondents have adopted fertilizers and improved seeds and had access to credit .

Inputs	Access to credit		N
	No	Yes	1539
Control (No inputs)	93	44	
percentage	**6.04**	**2.86**	
Organic Fertilizer	542	207	
Percentage	35.21767	13.450	
Inorganic Fertilizers	344	309	
Percentage	22.3816	20.07797	
Fertilizer use in %	**57.57**	**33.53**	
Control	93	44	1214
%	**7.66**	**3.62**	
improved seed	663	414	
%	**54.58**	**34.13**	

Table 6.Representation of agricultural inputs adoption and access to credit

For travertine adoption the findings show that55.46% of respondents did not adopt travertine and had not access to credit but 38.92% of respondents did not adopt while they had access to credit. On the other hand 2.43% of respondents have adopted travertine and had not access to credit whereas 3.19 % of respondents have adopted and had access to credit. The findings indicated that having accessibility to credit tend to increase number of farm household at 1.3times compare to the adopters without access to credit means that once farm households had access to credit would have adopted at extend of 1.3 times (annex 8). The results demonstrated that high number of farm households had not access to credit which reduce their willing to adopt inputs because of lack of purchase ability for agricultural inputs .The results are supported Adjognon *et al.,* (2017) found that credit access is limited in sub-Saharan Africa and undermine the adoption of inputs use.

4.1.2.3 Agricultural trainning

The results shows that 21.83% ,28.14% 34.10% and 44.66% of respondents did not adopt organic ,inorganic fertilizers ,improved seed and travertine respectively and did not received any agricultural training but 24.04 % 17.74%, 10.63% and 1.50 % of respondents have adopted organic ,inorganic fertilizers ,improved seed and travertine respectively and did not receive any agricultural training. Also 44.51%,11.11% ,27.43% and 50.20% of respondents did not adopt organic ,inorganic fertilizers ,improved seed and travertine respectively and had received agricultural training whereas 9.62%,43.10 %, 27.84 % and 7.41% of respondents have adopted and have received agricultural training (annex 9) .

The results revealed that agricultural trainings have increased the adopters with a factors of 2.42 ,2.61 and 11.11 on inorganic fertilizers, improved seed and travertineadoption respectively .The finding confirm a positive relationship between agricultural training and adoption of agricultural inptus . Similar results was found by Kennan and Ramappa (2017) who reported that training on inputs use and education have influenced pasitively and affect the adoption of soil nutrient technology. Also Pan and Zhang (2018) concluded that agricultural training improved the knowledge of fertilizer application to farmers via round table discussion on subject matter together with facilitators.

4.1.3. Biophysical factors

4.1.3.1 Land slope

The findings indicates that the agricultural inputs use change across land forms and it shows that 28.08%, 20,08% 46.38% of farm households have applied organic ,inorganic fertilizers and improved seed on very gentle slope farms respectively . It also illustrates that 10.53%, 14.55 % and 24.05% of respondent have applied, inorganic fertilizers and improved seed on moderate slope farms. The results exposed a decrease of agricultural inputs use from 48.15%, 25.08%, 0.78% and 0.65% of respondents that have applied fertilizers on very gentle slope, moderate slope, strong slope and very strong slope respectively (annex 10).Also 48%, 25,75% 2.26% 13.58% of respondent did not adopt travertine whereas 2.63%.1.98% 0.12% and 0.61 % of respondents have adopted travertine and land forms were very gentle slope , moderate slope , strong slope and very strong slope respectively (annex 11).

The results revealed that adoption of agricultural inputs varied depending on land forms and a greater number of farmhouseholds that had farms on gentle slope were more adopters campared to steep slope.The results disagree with the conclusion of Laekemariam *et al,.* (2016) reported that physiographic characteristics of agricultural land showed a none significant of fertilizer application by farm households but a grater decrease of manure application start in flat up to hill landscape. The results are consistent with Haefele *et al.*, (2010) believed that farmers applied farm manure and chemical fertilizers in flat plot because it gives good yield and explained that in middle and upper land low infiltration limit the predicted crop yield.

4.1.3.2. Farm size

The findings indicate that 84.15% , 76.68% and 83.61 % of respondents had less that one hactare of plot size (annex 12) on fertilizers,improved seeds and travetine perspective. Land fragmentation seems to be the main factor leading to small farm size and also high population growth expain smallfarmers possession due to sharing from parents to descendant .The results show that land size is not a limiting factor for agricultural inputs adoption in the study areas as agricultural inpus use have been seen for small farm holder and even big farm size . The results are consistent with Stephen (nd) reportedt that Japan and chine small farmhollder obtain levels of productivity per unit area of land which are equal to or greater than those achieved by large-scale farmers anywhere in the world, also he reported that the key to their success is not the size of their land holding but their access to intensifying farm inputs and particularly to inorganic fertilizers. The results are in line with Minagri(2018) demonstrated about 30 % of farmers own less than 0.2 ha accounting for about five per cent of total arable land while about 25 per cent cultivate more than 0.7 ha accounting for 65 per cent of the national farm-land.Also Ali, Awuni, &Danso (2018) acknowledged that keeping farm size constant, off farm activities, contact with extensions services family labor influence the adoption of fertilizers.

4.1.4.Economic factors

4.1.4.1 Off farm income

The table below shows that 5.46%, 6.92% of respondents did not adopt fertilizers and improved seeds and had not off farm income respectively whereas 3.44 % and 4.37 % of respondents did not adopted and had off farm income but 63.87 % and 60.46 % have adopted and had not off farm income whereas 27.23 % and 28.25% of respondents have adopted fertilizers and improved seeds and had off farm income respectively .

Input Use	Off farm income		n
	No	Yes	1539
Control (no input)	84	53	
percentage	**5.46**	**3.44**	
Organic Fertilizers	526	223	
percentage	34.18	14.48	
Inorganic Fertilizers	457	196	
percentage	29.69	12.73	
Fertilizers use in %	**63.87**	**27.23**	
Control	84	53	1214
Percentage	**6.92**	**4.37**	
improved seed	734	343	
Percentage	**60.46**	**28.25**	

Table 7.Representation of agricultural inputs and off farm income

For travertine adoption results indicates that 62.29% did not adopted and had not off farm income whereas 32.09% of respondents did not adopt travertine and had off farm income .On the other hand 3.72% of respondents have adopted and had not off farm income although 1.90% have adopted improved and had off farm income (annex 15). The results revealed that great number farm households had not off farm income .

Thus, this lack of off farm income affects negatively the adoption of agricultural inputs adoption.Off farm income offer ability to household farm investment in term pushasing agricultural inpus and labour hiring .The findings is suppoted by Awondo *et al*,. (2017) agreed that off farm income significantly reduces threats and individual constraints of fertilizers application also Martey, Kuwornu,, &Adjebeng-Danquah (2019) asserted that inorganic fertilizers use is determined by off farm income and farming history .

4.1.4.2 Liversock ower (Tropical livestock unit)

Results indicates that 5.78% and 7.33% of respondents did not adopt and had not livestock whereas 3.12% and 3.95 % of respondents did not adopt while had livestock. Moreover,16.96% and 22.91% of respondents have adopted and had not livestock also 74.14% and 65.8% have adopted fertilizers and improved seeds respectively and had livestock (annex 16) .The tenancy of livestock increases the adoption level with a factor of 4.37 and 2.87 times on fertilizers and improved seeds adoption respectively. The results indicated that livestock ownership influence positively the adoption of agricultural inputs.

For travertine adoption, the findings shows that 21.42 % did not adopt travertine and had not livestock whereas 72.96% did not adopted while had livestock, in addition to that 0.61% have adopted and had not livestock whereas 5.01% of respondents have adopted and had livestock (annex 17).The findings showed that livestock owner affect positively the adoption of travertine and it is explained by 8,21 factor.Livestock is wealth indicator that determine the purshaing power of farm household .Similar results were found by Alem& Broussard (2018) admitted that fertilizers application intensity increase depending on livestock possession by farm households. Furthermore, Terefe and Ahmed (2016) demonstrated that the level of organic fertilizers application estimation is based on livestock ownership, land forms and access to credit.

4.1.5 Perception attitudes

The table below summarizes farm household perceptions on agricultural inputs and It shows that 49.39 % ,25.65% , 24.84% 2.36 %36.05% and 63.36% of respondents did not know the effect of NPK,DAP,UREA,Manure,Compost , and Travertine respectively .Also it indicates that 1.81% ,2.40% ,2.99%, 9.84%,9.03% and 4.02 % of respondents had not enough information about the effect of NPK,DAP,UREA,Manure,Compost , and Travertine respectively.

On the other hand 47.88%, 71.25% ,71.25 % 87.14 %, 53.41% and 31% of respondents had information on the effect of NPK,DAP,UREA,Manure,Compost , and Travertine respectively.

Agricultural inputs	*Effect of Input*				*n*
A. Input use	*Don't know*	*Increase little*	*Increase lots*	*None*	*1531*
1. NPK	*760*	*28*	*737*	*6*	
Percentage	**49.39**	**1.81**	**47.88**	**0.41**	
2. DAP	*395*	*40*	*1096*	*4*	*1535*
Percentage	**25.65**	**2.40**	**71.25**	**0.26**	
3. UREA	*382*	*46*	*1097*	*8*	*1533*
Percentage	**24.84**	**2.99**	**71.25**	**0.44**	
4. Manure	*36*	*151*	*1341*	*4*	*1532*
Percentage	**2.36**	**9.84**	**87.14**	**0.29**	
5. Compost	*555*	*139*	*822*	*18*	*1534*
Percentage	**36.05**	**9.03**	**53.41**	**1.14**	
6. Travertine	*975*	*62*	*477*	*17*	*1531*
Percentage	**63.36**	**4.02**	**31.00**	**1.11**	

Table 8.Representation of agricultural inputs and farm household's perception

The results indicated that a big number of farm household did not know the effect of agricultural inputs wich influence negatively the adoption .

Similarly, a study conducted by Rushemuka, Bizoza,Mowo and Bock (2014) concluded that the knowledge of soil and fertilizers types help farmers to use technology for improve soil fertility management. Recently, Seline *et al.*, (2015) concluded that farmer's knowledge, awareness and thoughts have a significant impacts on adoption of modernized crop practices .

4.1.6 Soil management practices (Agroforestry ,Irrigation and intercropping)

The table below summarizes the agricultural inputs use and some soil management practices. A survey conducted has shown that 5% , 8.44%, 0.45% 5.26% 3.44% % and 0.19% of respondents neither adopt any fertilizers nor implemented agroforestry, and [inter,mon ,both]intercropping respectively . In addition, Also 3.89% 0.45% of farmers have implemented agroforestry and irrigation practices respectively but they did not adopt fertilizers. Moreover, 38.34%, 74.54% of household farmers have adopted fertilizers with no adoption of agroforestry and irrigation while 52.76% and 16.57 % of respondents have adopted fertilizers as well as agroforestry and irrigation. Also 36.58%, 52.31% and 2.21% implemented intercropping, monoculture and both system and adopted fertilizers.

In addition 6.34% 10.7 did not adopt improved seeds and have not implemented agroforstry and irrigation respectively while 6.7%, 4.4% and 0.2% implemented intercropping, monoculture and both system respectively whereas 34% and 65.9% have adopted improved seeds and did not implement agroforstry and irrigation practices accordingly . Also 53.99% and 22.8% have adopted improved seeds and have used agroforestry and irrigation. It also shows 34.62%, 50.51% and 3.57% of respondents have adopted improved seeds and have used intercropping, monoculture and both system respectively. The results showed farm households that have managed trees on their farms have adopted fertilizer. It also revealed that monocropping influence positively fertilizers use.

The results on adoption of travertine in relation to others soil management's practices including agroforestry shows that 38.88% did not adopt travertine and agroforestry while 2.06% have adopted travertine and did not implement agroforstry practices whereas 55.46 % did not adopt travertine and have implemented agroforestry thought 3.56% have adopted and implemented agroforestry practices (annex 18).

Input use	Agroforestry		Irrigation		Intercropping			n
	No	Yes	No	Yes	Inter	Mono	Both	1539
Control	77	60	130	7	81	53	3	
Percentage	**5.00**	**3.89**	**8.44**	**0.45**	**5.26**	**3.44**	**0.19**	
Organic Fertilizer	345	404	667	82	367	363	19	
Percentage	22.42	26.25	43.34	5.33	23.85	23.59	1.23	
Inorganic Fertilizers	245	408	480	173	196	442	15	
Percentage	15.92	26.51	31.19	11.24	12.73	28.72	0.97	
Fertilizer use in %	**38.34**	**52.76**	**74.53**	**16.57**	**36.58**	**52.31**	**2.21**	
Control	77	60	130	7	81	53	3	1214
%	**6.34**	**4.94**	**10.7**	**0.6**	**6.7**	**4.4**	**0.2**	
Improved seed	422	655	800	277	420	613	43	
%	**34**	**53.99**	**65.9**	**22.8**	**34.62**	**50.51**	**3.57**	

Table 9.Representation of agricultural inputs and some soil management practices

The results on adoption of travertine use and irrigation shows that 75.26% did not adopt travertine and did implement irrigation practices while 4.32% have adopted travertine and did not implement irrigation whereas 19.12% did not adopt travertine and have implemented irrigation practices . On the other hand 1.29% of respondents have adopted travertine and have implemented irrigation systems (annex 19)

For the adoption of travertine in relation to intercropping systems results shows that 3, 84%, 35.37% and 55.17% of respondents did not adopt travertine and interchanged both intercropping and monoculture systems, intercropping and monoculture systems respectively it also indicates that 0.12 %, 1.62% and 3.88%of respondents have adopted travertine and interchanged both intercropping and monoculture systems, intercropping and monoculture systems respectively (see annex 20). Mathuya *et al* .,(1998).found that seasonal litter fall provide soil nutrient that meet crop demand and enhance nutrients cycling and reduce the amount of inputs applied for next seasons .also Mohammad *et al*.,(2008) agreed that soil amendment application such agrochemicals inputs in farms managed with biological nitrogen fixation trees species has economical viability compared to sole plantation.

4.1.7. LOGISTIC REGRESSION MODELS

4.1.7.1. Inorganic fertilizers adoption model

Results from Regression analysis indicate that farm types, irrigation use agricultural training and land form characteristics were statistically highly significant at (p=0.01) and were positively related with inorganic fertilizers adoption as well as access to credit was statistically significant at (p=0.05) of significance level. Farm labor (reciprocal) and cropping system (intercropping) were negatively related and statistically significant (p=0.05) affect the decision of inorganic fertilizers adoption. The probability to adopt is estimated by logit coefficient by dividing with 4 factors as linear probability is not straightforward (Maddala, 1983) .Therefore keeping others variables constant, the probability to adopt for farmers from farmer types 9 (Cropping champion was greater at 89.5% compare to traditional farm types and having irrigation and agricultural training access had probability of 57% and 75% respectively for inorganic fertilizers adoption. In addition, results shows that access to credit influenced positively the adoption of inorganic fertilizers at 34% whereas farm labor (reciprocal) and cropping system (intercropping) were negatively related the adoption of inorganic fertilizers adoption at 26% and 77% respectively.

Significant variables	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
Farm types : 2	.6831639	.8779684	0.78	0.436	-1.037623	2.40395
3	3.09867	.7150953	4.33	0.000	1.697109	4.500231
4	3.121243	.6398084	4.88	0.000	1.867242	4.375245
5	3.17738	.7221542	4.40	0.000	1.761983	4.592776
6	3.38437	.6905919	4.90	0.000	2.030835	4.737905
7	3.276287	.6963925	4.70	0.000	1.911382	4.641191
8	3.289744	.7069791	4.65	0.000	1.90409	4.675397
9	3.050998	.6585637	4.63	0.000	1.760237	4.341759
10	3.586103	.642521	5.58	0.000	2.326785	4.845421
Farm labour:5	-2.626838	1.28491	-2.04	0.041	-5.145215	-.1084616
Land slope :2	1.48459	.5319386	2.79	0.005	.4420096	2.527171
6	1.703396	.4996389	3.41	0.001	.7241216	2.68267
Irrigation practices	.5733053	.1514957	3.78	0.000	.2763793	.8702314
Agricultural training	.7598899	.1368747	5.55	0.000	.4916205	1.028159
Access to credit	.3430964	.1291819	2.66	0.008	.0899045	.5962882
Cropping system: 1	-.7799809	.3354335	-2.33	0.020	-1.437418	-.1225434
Constant	-3.549383	.9343621	-3.80	0.000	-5.380699	-1.718067

Table 10.Logistic regression model for inorganic adoption,

Note: Farm labor 5: reciprocal, land slope 2: gentle: 6: moderate, cropping system: 1 Intercropping

The correlation matrix presented shows that multicollinearity was not a concern, because none of the explanatory variables were strongly connected with each other (annex 21).The results are consistent with Obisesan, Akinlade, Fajimi (2013) stated that access to credit, and fertilizer price and education are the most factors that influence fertilizers use by farmers. Recent findings of Laekemariam *et al.*,(2016) indicated that cost of fertilizers, availability of credit, time delivery delay and unpredicted climatic factors decrease farmers willingness to use mineral fertilizers.

4.1.7.2. Travertine adoption model

The table below indicates that farm types (Elite land owners and cropping champions) had positive relationships and had no statistical significant on adoption decision while agro ecological zone, agricultural training, and credit access were statistically significant at (p=0.05) whereas land tenure was negatively related and was statistically significant .The probability for adoption is estimated by 28.5% and 28% for farm types 9 and 10 respectively. Being in western agro ecological zone of Rwanda had high probability to adopt travertine at 84% compare to others agro ecological zones .The difference in adoption of travertine across agro ecological zone is because Western province has high acidity compare to others region as it has high rain fall inducing soil degradation.

Also results indicates that agricultural training had 69% of probability to increase the adoption decision whereas access to credit had 48.5% to influence the adoption of travertine .Land tenure in form of communal land was negatively related and statistically significant (p=0.05) affect the adoption of travertine at 83%..

Significant variables	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]
Farm types : 9	1.141891	.6817296	1.67	0.094	-.1942741 2.478057
10	1.128561	.6539138	1.73	0.084	-.1530867 2.410208
Ago ecological zone :3	.8416029	.269884	3.12	0.002	.3126399 1.370566
Land tenure :3	-.8396	.421292	-1.99	0.046	-1.665317 -.0138828
Agricultural training	.6918152	.2235603	3.09	0.002	.2536452 1.129985
Access to credit	.4856128	.2010691	2.42	0.016	.0915247 .8797009
Constant	-4.431413	1.146691	-3.86	0.000	-6.678887 -2.183939

Table 11.Logistic regression model for travertine adoption, Note: Land tenure 3: Communal land

The correlation matrix shows that multicollinearity was not a concern, since none of the explanatory variables were strongly correlated with each other (annex 23).

4.1.7.3. Improved seeds adoption model

The table below shows regression results and indicates that farm types, agroforestry practices, agricultural training, irrigation practices had positive relationships and affected highly significant at (p=0.01) the adoption of improved seeds. Moreover land slope characteristic had positive relationship and affected significantly at (p=0.05) the adoption decision of improved seeds whereas cropping system such as intercropping were negatively related and affected significantly the adoption of improved seeds .The adoption probability is estimated by dividing by 4 the logit model coefficient (Maddala,1983) and revealed that keeping others variable constant farm types 3,4,5,6,7,8,9,10 had 72%,71.5% 72%,74.75%,70.25,79.75%,72% and 83.75% respectively .

It also depicts that farm labor (hire labor), irrigation practices, agroforestry, agricultural training and access to credit had 86%, 59%, 74.5%, 74.1% and 37% probability for improved seeds adoption.

Significant variables	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
Farm types : 2	.3519575	.9805599	0.36	0.720	-1.569905	2.27382
3	2.881868	.7420793	3.88	0.000	1.427419	4.336317
4	2.865643	.6588036	4.35	0.000	1.574412	4.156874
5	2.884128	.7490945	3.85	0.000	1.41593	4.352327
6	2.995391	.7108824	4.21	0.000	1.602087	4.388694
7	2.811718	.719632	3.91	0.000	1.401265	4.222171
8	3.196258	.7313824	4.37	0.001	1.762775	4.629742
9	2.881248	.6807004	4.23	0.000	1.547099	4.215396
10	3.352611	.6616033	5.07	0.000	2.055892	4.64933
Farm labor :4	.8637215	.5245996	1.65	0.100	-.1644749	1.891918
Land slope :2	1.468273	.5474657	2.68	0.007	.3952597	2.541286
6	1.6094	.5678852	2.83	0.005	.4963653	2.722434
Irrigation practices	.5985187	.1739055	3.44	0.001	.2576701	.9393673
Agroforestry	.7456553	.171593	4.35	0.000	.4093393	1.081971
Agricultural .training	.7412042	.1578568	4.70	0.000	.4318105	1.050598
Access to credit	.3715917	.1473173	2.52	0.012	.0828552	.6603282
Cropping system : 1	-.6798955	.3633857	-1.87	0.061	-1.392118	.0323273
Constant	-3.425715	1.001106	-3.42	0.001	-5.387847	-1.463583

Table 12. Logistic regression model for improved seeds adoption. Note: farm labor4: Hire labor

Also multicollinearity was not a concern (annex24). The results are supported by Ouma *et al.*, (2002) found that agro ecological zones, labor hiring, and extension services were statistically significant affect farmer's adoption of improved maize variety.

Additionally results are consistent with Makate, C., Makate, M., & Mango, (2018) who reported that adoption of agricultural practice friendly to climate is defined by socioeconomic determinants and clusters and found that farm typology is essential to promote smart climate agriculture.

4.2. Discussion of results

4.2.1. Inorganic fertilizers adoption

The results indicate that inorganic fertilizers adoption varies between farm types .The significance difference is linked to wealth status , education level and production orientation of farm households .The more adoptes were from farm types 10,9,8 and 7 because of they are wealthier whereas low adopters (farm types 1,2,3 and 4) are due to low education of farmers and they are poor compare to other farm groups . These implies education increases farm household ability to reach agricultural information and reinforce logical capability to the use of inorganic fertilizers. Furthermore, wealth status enhanced adoption of inorganic by increase purchasing ability for farmers.

Also the differences among farmers are due their different farm management skills, access to information, livestock ownership, and opinion to input efficacy use and off farm employment. Moreover adoption decisions differ from one farm types due to agricultural finance and access to credit (Emmanuel *et al.*, 2016), Farm diversity affords important aspect to maintain innovation technology adoption and policy based on diversity of concerned population. (Dupré, Michels, and Le Gal, 2017).

Adoptions of inputs rely on other technology like irrigation practice that reduces production risk (Koundouri *et al.*, 2006). The presence of irrigation practices influence farm household to adopt because irrigation practices supplement water required to solubilize inorganic fertilizers and water availability can best taken to solve the problem of crop failure and farm households would be probable to adopt agrochemical inputs. Irrigation practices contribute to crop water demand and farmers don’t expect not only water stress but also germination failure and inefficient use of fertilizer. Harvest, (2010) reported that rain fed agriculture is challenged by rainfall variability which decreases farm investment of new.

Additionally inorganic fertilizers adoption has positive relationship with agricultural training because it provide the knowledge, awareness and relevant information of subject matter and farmers be informed and ask where obstacle has been raised to satisfy their curiosity on agriculture innovation. Similar results was found by Kennan and Ramappa (2017) who reported that training on inputs use and education have influenced pasitively and affect the adoption of soil nutrient technology. Furthemore access to credit increase the adoption through increasing farm household ability to purshase the inputs use and it also helps to reduce the problems that farm household are encountered during agricultural activities. Dan and Ning,(2018) agreed that agricultural training is a prerequisite for effective fertilizer management and improving farmers knowledge on agricultural inputs use

Farm labor (reciprocal) and cropping system (intercropping) has negative relationships and affect significantly the decision of inorganic adoption since fertilizers application is labor intensive and agricultural inputs use requires man power for every stage for effective crop productivity level (Umar., Okoye and Agwale,2011).

Reciprocal farm labor affect negatively the adoption once delayed exchange occurs whereas intercropping has risk to reduce crop yield through competition for light , soil nutrient and water which effect actual and predicted crop yield , also high cost of farm management example weeding practices remains obstacles to adopt inorganic to be applied on farm under intercropping system . Moreover land form characteristic like gentle and moderate slope define inputs use based on degradation extent where farmers incline to invest on agricultural inputs and the most undermine feature are steppe slope where farmers pretend a high degraded land form due to erosion and others degradation factors. Rowarth *et al.,* (1992) reported that after phosphate fertilizers application residual phosphorus decrease with soil depth and land slope where high land slope has low phosphorus cycling. Farmers invest on land based on its capability and suitability to improve the outcome. Scientifically applied of inorganic fertilizers on steep slope reflect the wash away of inputs due to erosion which conduct to eutrophication in low land and aquatic environment and others externalities constraint (Huang *et al.,* 2017)

4.2.2. Travertine adoption

The results reveal travertine adoption variability among farm types where farm types (Elite land owners and cropping champions) are more adopters compare to traditional farmers because are the most prosperous in terms of income and livestock ownership. Ownership of land motivate farm household to invest in travertine because liming material including travertine have residual effect and if farm household do not have ownership right, they become reluctant. Possibly, owning an arable land could best be taken as a prerequisite to adopt and employ agricultural technologies since farmers could incur a cost. Being a rational decision maker, while incurring a cost for technologies, farmers want totally to take up technologies within their own land. According to Myyrä, Pietola and Yli-Halla, (2007) farmers rapidly diminish investments in permanent land improvements and thereafter, yields decline slowly. The simulations highlight the observed trends of decreasing land improvements on land parcels that are cultivated under lease contracts. As farm types have their characteristics such as land ownership, resources endowment, production orientation, land size and livestock (Renske *et al.,* 2013). Land tenure in form of communal land decrease the adoption of travertine application through the tragedy of common where every arm household is interest to own interest.

Travertine has residual effect and better effectiveness of travertine is obtained when applied in small amounts and more often (Gibberd, 1995).These advantageous effects are distributed over a longer time than those of seasonal application.

Secondly the positive relationship between travertine adoption and agro ecological zone is due to soil acidity variability across agro ecological zone and the more acidity reflects the adoption. High levels of acidity are attributed to natural causes and at times, due to acidifying fertilizers previously used. Lime has shown a long time effect which requires an update (Nduwumuremyi et al., 2013). A study conducted by Lawin and Tamini (2019) and Goswami(2015) indicated that land tenure arrangement significantly persuade farmers' decision to invest in agri-environmental practices. The intensity of the adoption of agri-environmental practices is consistently higher on owned plots than borrowed, rented or sharecropped plots. Thirdly agricultural training plays a significant role in diffusion of new innovation and found that farmer adoption rate increase after training (Nakano,Tsusaka, Aida and Pede,2018).

This may be clarified by the fact that the message/contents that farmer gain from trainers help them to kick off the use newly introduced land management practices on their farm to care for their land from soil acidity and improve its fertility. Mpaweniman, (2005) found that accessibility to credit reduce farmer's constraint while proposing to pay for agricultural inputs; and hence paves the way for timely application of inputs thereby enhance the overall productivity and farm revenue .

4.2.3. Improved seeds adoption

Like others agricultural inputs, the adoption of improved be different across farm types based on their demographic livelihoods, farm management, farm productivity and perception on modernized agricultural practices .There general trends where farm types 10,9,8 and 7. are more users compare farm types 1,2,3 and 4 is correlated with education, production orientation and livestock ownership and their perception on inputs efficacy. irrigation practices have positive relationships and affect highly significant at (p=0.01) the adoption of improved seeds because irrigation practices can control water availability problem and water stress and it can sustainable solution to the problem of crop failure and farm households would be motivated to adopt improved seeds (El Balla, Hamid and Abdelmageed, 2013).

Additionally, agroforestry practices affect the adoption of improve seeds because it improves soil fertility status by maintaining soil organic matter and by fixing nitrogen from the atmosphere. The adoption of agricultural inputs are positively correlated with agroforestry for the fact that agroforestry practices prevent soil erosion and nutrient loss and thereafter increase crop yield .In addition agroforestry provide other sources of income not only timber, fuel wood, stakes for climbing beans required by farm households but also it works as source of income helping farm to purchase agricultural inputs. Furthermore ,agricultural training also indicates a positive impact on improved seeds adoption because it is a channel to deliver the benefit the use of improved seed, the study conducted by Pan and Zhang (2018) indicated that advocacy for farmers to be skilled and advised to adopt yield-raising technologies such as organic manure, improved seeds appropriate for local conditions and modern agricultural machinery would be an added asset to assist their farming activities to improve poverty reduction.

Moreover land slope characteristic have positive relationship and affect significantly at (p=0.05) the adoption decision of improved seeds

Cropping system such as intercropping has negative relationship and affects significantly adoption of improved seeds compare to Monocropping which makes the farm activities such as water and fertilizer management, weeding, harvesting easier. It is also very convenient for field mechanization. Large-scale agricultural operations like grain productions and plantations usually follow mono-cropping patterns of cultivation for the efficient utilization of limited resources and it helps scheduling casual works. In terms of cropping systems, the solutions may not only involve the mechanized rotational mono-culture cropping systems used in developed countries but also the poly-culture cropping system traditionally used in developing countries (Tsubo et al., 2003). There are, however, some disadvantages in intercropping systems. These includes yield reduction of the main crop, loss of productivity during drought periods, and high labor inputs in regions where labor is scarce and expensive (Gliessman, 1985). It is well documented that in most cases the main crop in an intercropping system will not reach as high a yield as in a monoculture, because there is competition among intercropped plants for light, soil nutrients and water (Willey, 1979b). Another disadvantage that is likely to be occurring is the higher cost of maintenance, in particular, weeding, which may have to be done by hand.

Empirical results indicate that different types of credit such traditional credit, informal and formal allow farm household to buy appropriate inputs and credit access , insurance and reserves may stimulate technology adoption where new methods are riskier but higher-yielding or require sunk costs(Adjognon, Liverpool-Tasie, & Reardon, 2017; Farrin and Miranda,(2015).

Additionally access to credit increase the adoption of improved seed by increase farm household ability to purchase inputs, engage labor, upholding cost, farm management and counter the effect of climate variability. According to Peprah and the research team (2017) confirmed the significant roles that credit plays in yield-raising technologies such as improved seed varieties, fertility-restoring and conservation technologies can play in improving the yield of rural smallholder farmers.

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CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The present study was intended to assess farm household based factors affect the adoption of agricultural inputs namely inorganic fertilizers, organic fertilizers, travertine and improved seeds in Rwanda specifically in Western, Eastern and Southern province of Rwanda. Agricultural inputs application is an essential strategy for increasing agricultural productivity, achieving food self-sufficiency and alleviating poverty and food insecurity among smallholder farmers in Rwanda. In the study areas, farm households have adopted and using different agricultural inputs but the adoption were not completely optimal yet. Addressing interwoven problems linked to low adoption of agricultural inputs is a paramount and understanding farmer's heterogeneity is useful tools for public and private to scaling up agricultural development in rural areas.

Regression results reveal that farm types, irrigation use and agricultural training have highly significant effects at (p=0.01) and have positive relationships with inorganic fertilizers adoption as well as access to credit, farm labor and cropping system have affected significantly at (p=0.05) but cropping system and farm labor have negative relationships. Moreover farm types have positive relationships and has no significantly affect on the adoption of travertine while agro ecological zone, agricultural training and access to credit have significant effects at (p=0.05). Besides, farm types, agroforestry practices, agricultural training, irrigation practices have positive relationships and affect highly significant at (p=0.01) the adoption of improved seeds. Moreover land slope characteristic have positive relationships and affect significantly at (p=0.05) whereas cropping systems such as intercropping has negative relationship and affect significantly adoption of improved seeds.

Results showed that access to credit, agricultural training, irrigation practices and cropping systems (monocropping) was the most driving factors for agricultural inputs adoption in the study areas. Farm typologies captured a defined association between agricultural inputs adoption and farm types.

Lastly the uptake of agricultural technologies is a complex process influenced by both extrinsic and intrinsic variables and proper adoption of agricultural inputs need to address multiple constraints simultaneously.

5.2. Recommendations

Based on the findings regarding to farm households based factors affecting agricultural inputs adoption in Rwanda specifically in Western, Eastern and South province ,the following recommendation should be taken into consideration at all level

- **PUBLIC AND PRIVATE SECTORS**

1. The current farm typologies should be applied nationally and support programmes tailored to them & Farmers allocation.
2. Strengthening and provision of inputs subsidy programs.
3. Promotion of Problem centered Agricultural training & seminar and community outreach.
4. Promotion of agroforestry and irrigation practices at household level.
5. Interventions to increase adoption of agricultural inputs like travertine, inorganic fertilizers and improve seeds can enhance access to credit, irrigation and agricultural training.

- **AREAS FOR FURTHER RESEARCH**

6. Quantification of fertilizers and travertine levels required in different agro ecological zones.
7. Feasibility study on crop index based insurance that allow farmers to takeout environmental risks

REFERENCES

Adjognon, S. G., Liverpool-Tasie, L. S. O., & Reardon, T. A.(2017). Agricultural input credit in sub-Saharan Africa: Telling myth from facts. Food Policy, 67, 93-105. doi:10.1016/j.foodpol.2016.09.014

Alem, Y., Broussard, N. H., (2018).The impact of safety nets on technology adoption: A difference-in-differencesanalysis.AgriculturalEconomics,49(1),13-24. doi:10.1111/agec.12392

Ali, E. B., Awuni, J. A., &Danso-Abbeam, G.(2018). Determinants of fertilizer adoption among smallholder cocoa farmers in the western region of ghana. Cogent Food & Agriculture, 4(1) doi:10.1080/23311932.2018.1538589

Awondo. N.,Ramirez, O. A.,Colson, G. J., Fonsah, E. G., &Kostandini, G. (2017). Self-protection from weather risk using improved maize varieties or off-farm income and the propensity for insurance. Agricultural Economics,48(1), 61-76. doi:10.1111/agec.12295

Berihun KassaH.,BihonKassa A &Kibrom Aregawi W.,(2014).Adoption and impact of agricultural technologies on farm income: evidence from southern Tigray northern Ethiopia: International Journal of Foodand Agricultural Economics ISSN 2147-8988 Vol. 2 No. 4, (2014), pp. 91-106

Bidogeza J. C, Berentsen. P. B. M, De Graaff , J, &Oude Lansink A. G. J. M. , (2009) A typology of farm households for the Umutara Province in Rwanda

Bucagu,C.Vanlauwe,V. Mark T. Van Wijk& Ken E. Giller (2014). Resource use and food self-sufficiency at farm scale within two agro-ecological zones of Rwanda

Chappell, M. J., & LaValle, L. A.(2011). Food security and biodiversity: Can we have both? An agroecological analysis.Agriculture and Human Values, 28(1), 3-26. doi:10.1007/s10460-009-9251-4

Dan P.,& Ning .Z.(2018).The Role of Agricultural Training on Fertilizer Use Knowledge: A Randomized Controlled Experiment

Dimitris K., Stelios .R., &Ioannis, A. (2015).Dealing with farm heterogeneity on modeling agricultural policy: An Agent Based Modeling Approach

Dunjana .N, Zengeni.R., Muchaonyerwa.P.,&Wuta.M (2018).Typological characterization of farms in a smallholder food-cash crop production system in Zimbabwe opportunities for livelihood sustainability.

Dupré, M., Michels, T., &Le Gal, P. (2017).Diverse dynamics in agroecological transitions on fruit tree farms.European Journal of Agronomy,90, 23-33. doi:10.1016/j.eja.2017.07.002.

El Balla, M. M. A., Hamid, A. A.,& Abdelmageed, A. H. A. (2013). Effects of time of water stress on flowering, seed yield and seed quality of common onion (allium cepa L.) under the arid tropical conditions of sudan. Agricultural Water Management, 121, 149-157. doi:10.1016/j.agwat.2013.02.002

Emmanuel, D., Owusu-Sekyere, E., Owusu, V., & Jordaan, H. (2016). Impact of agricultural extension service on adoption of chemical fertilizer: Implications for rice productivity and development in Ghana. NJAS - Wageningen Journal of Life Sciences, 79, 41-49. doi:10.1016/j.njas.2016.10.002

Farrin, K., & Miranda, M. J. (2015).A heterogeneous agent model of credit-linked index insurance and farm technology adoption. Journal of Development Economics, 116, 199-211. doi:10.1016/j.jdeveco.2015.05.001

Frossard, E., &Vlek, P. L. G. (2014). Socio-economic and biophysical determinants of land degradation in Vietnam: An integrated causal analysis at the national level. Land Use Policy, 36, 605-617. doi:10.1016/j.landusepol.2013.10.012

Garini, C. S., Vanwindekens, F., Scholberg, J. M. S., Wezel, A., & Groot, J. C. J. (2017). Drivers of adoption of agroecological practices for winegrowers and influence from policies in the province of Trento, Italy.Land use Policy, 68, 200-211. doi:10.1016/j.landusepol.2017.07.048

Gibberd V, (1995). Yield responses of food crops to animal manure in semi-arid Kenya. Tropical Sciences, 35: 418-426.

Giller, K.E., Tittonell, P., Rufino, M.C., van Wijk, M.T., Zingore, S., Mapfumo, P., Adjei-Nsiah, S., Herrero, M., Chikowo, R., Corbeels, M., Rowe, E.C., Baijukya, F., Mwijage, A., Smith, J., Yeboah, E., van der Burg,W.J., Sanogo, O.M., Misiko, M., de Ridder, N., Karanja, S., Kaizzi, C., K'ungu, J., Mwale, M., Nwaga, D.,Pacini, C., Vanlauwe, B., 2011. Communicating complexity: Integrated assessment of trade-offs concerning soil fertility management within African farming systems to support innovation and development. Agricultural Systems 104, 191-203.

Gliessman, S.R., (1985). Agro-Ecological Processes in Sustainable Agriculture. Sleeping Bear Press, Chelsea, ML, USA.

Goswami, B. (2015). Does Tenure Status Affect the Adoption of Land Productivity Enhancing Practices and Input Intensities?Evidence from Assam Plains in India’s Northeast.Journal of Land and Rural Studies, 3(1), 29–44. https://doi.org/10.1177/2321024914534040

Haefele, S. M., Sipaseuth, N., Phengsouvanna, V., Dounphady, K., &Vongsouthi, S. (2010). Agro-economic evaluation of fertilizer recommendations for rainfed lowland rice. Field Crops Research, 119(2), 215-224. doi:10.1016/j.fcr.2010.07.002

Hammond Jim ,Nathaniel Rosenblum , Dana Breseman, Leo Gorman , Mark van Wijk, Rhys Manners , Milindi Sibomana, Bernard Vanlauwe, Marc Schut.(2018).Farm household typologies for more effective rural development interventions in Rwanda

HarvestChoice, (2010). Rainfall Variability and Crop Yield Potential.International Food Policy Research Institute, Washington, DC., and University of Minnesota, St. Paul, MN. Available online at http://harvestchoice.org/node/2240.

Huang, J., Xu, C., Ridoutt, B. G.,Wang, X., & Ren, P. (2017). Nitrogen and phosphorus losses and eutrophication potential associated with fertilizer application to cropland in china. Journal of Cleaner Production, 159, 171-179. doi:10.1016/j.jclepro.2017.05.008

Kamanga BCG (2011).Poor people and poor fields? Integratinglegumes for smallholder soil fertility management in Chisepo,central Malawi. PhD thesis, Research School forResource Studies for Development, WageningenUniversity

Kannan, E., &Ramappa, K. B. (2017). Analysis of farm-level adoption of soil nutrient management technology by paddy farmers in karnataka, india. Environment, Development and Sustainability, 19(6), 2317-2331. doi:10.1007/s10668-016-9858-8

Karamage, F., Zhang, C., Ndayisaba, F., Shao, H., Kayiranga, A., Fang, X.,Tian, G. (2016). Extent of Cropland and Related Soil Erosion Risk in Rwanda. Sustainability, 8(7). doi:10.3390/su8070609

Kebede, B., (2007). Community wealth-ranking and household surveys: An integrative approach. Q-Squared Working paper No. 38, Centre for International Studies, University of Toronto, Canada.

KNOEMA,(2019).Fertilizer consumption per unit of arable land. Retrieved 27/6/2019 at https://knoema.com/atlas/Rwanda/Fertilizer-consumption

Kotchikpa G. Lawin& Lota D. Tamini(2019)Land Tenure Differences and Adoption of Agri-Environmental Practices: Evidence from Benin,The Journal of Development Studies,55:2,177-190,DOI:10.1080/00220388.2018.1443210

Koundouri, P., Nauges, C., &Tzouvelekas, V. (2006). Technology adoption under production uncertainty: Theory and application to irrigation technology. American Journal of Agricultural Economics, 88(3), 657-670. doi:10.1111/j.1467-8276.2006.00886.x

Kristen J. Augustine (2016). Integrating Gender and Nutrition within Agricultural Extension Services RWANDA Landscape Analysis

Laekemariam, F., Kibret, K., Mamo, T., Karltun, E., &Gebrekidan, H.(2016). Physiographic characteristics of agricultural lands and farmers' soil fertility management practices in wolaita zone, southern ethiopia. Environmental Systems Research, 5(1), 1-15. doi:10.1186/s40068-016-0076-z

Lawin, K. G., &Tamini, L. D. (2019). Land tenure differences and adoption of agri-environmental practices: Evidence from benin. The Journal of Development Studies, 55(2), 177-190. doi:10.1080/00220388.2018.1443210

Maddala, G.S. 1983.Limited Dependent and Qualitative Variable inEconometrics. Econometric Society Monographs, CambridgeUniversity Press.

Makate, C., Makate, M., & Mango, N. (2018).Farm household typology and adoption of climate-smart agriculture practices in smallholder farming systems of southern africa. African Journal of Science, Technology, Innovation and Development, 10(4), 421-439. doi:10.1080/20421338.2018.1471027

Marenya, P. P., & Barrett, C. B.(2007). Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western kenya. Food Policy, 32(4), 515-536. doi:10.1016/j.foodpol.2006.10.002

Marian W.,(2017)Understanding Farmer Motivation and Attitudes Regarding the Adoption of Specific Soil Best Management Practices

Martey, E., Kuwornu, J. K. M., &Adjebeng-Danquah, J.(2019). Estimating the effect of mineral fertilizer use on land productivity and income: Evidence from ghana. Land use Policy, 85, 463-475. doi:10.1016/j.landusepol.2019.04.027

MINAGRI (2018) .Strategic Plan for Agriculture Transformation 2018-24

Mitchelll ,D.(2008).A Note on Rising Food Prices

Mpawenimana, J. (2005). Analysis of Socio-Economic Factors Affecting the Production of Bananas in Rwanda: A Case Study of Kanama District. University of Nairobi

Myyrä, S., Pietola, K.,& Yli-Halla, M. (2007).Exploring long-term land improvements under land tenure insecurity.Agricultural Systems, 92(1), 63-75. doi:10.1016/j.agsy.2006.02.009

Nakano, Y., Tsusaka, T. W., Aida, T., &Pede, V. O. (2018). Is farmer-to-farmer extension effective? the impact of training on technology adoption and rice farming productivity in tanzania. World Development, 105, 336-351. doi:10.1016/j.worlddev.2017.12.013

National Institute of Statistics of Rwanda (NISR), EICV5 Main Indicators Report,November 2018

Nduwumuremyi, A.; Mugwe, N. J.;Rusanganwa, C. A.;Mupenzi, J.(2013).Mapping of limestone deposits and determination of quality of locally available limestone in Rwanda:Journal of Soil Science and Environmental Management

NISR (2015).Comprehensive Food Security and Vulnerability Assessment

NISR (2015-2016).Rwanda Demographic and Health Survey (2014/2015)

Niyitanga F. Kabayiza.A.,&Niyonzima J.P.,(2015). Assessment of Mineral Fertilizer Use se in Rwanda: International Journal of Agriculture Innovations and Research

Ogada, M. J.,Mwabu, G., &Muchai, D. (2014). Farm technology adoption in kenya: A simultaneous estimation of inorganic fertilizer and improved maize variety adoption decisions. Agricultural and Food Economics, 2(1), 1-18. doi:10.1186/s40100-014-0012-3

Otsuka, K., &kalirajan, K. P. (2006). rice green revolution in asia and its transferability to africa: An introduction. The Developing Economies, 44(2), 107-122. doi:10.1111/j.1746-1049.2006.00009.x

Ouma, J., F. Murithi, W. Mwangi, H. Verkuijl, M. Gethi, and H. De Groote. (2002).Adoption of Maize Seed and Fertilizer Technologies in Embu District, Kenya. Mexico, D.F.: CIMMYT

Pan, D.,& Zhang, N. (2018). The role of agricultural training on fertilizer use knowledge: A randomized controlled experiment.EcologicalEconomics, 148, 77-91. doi:10.1016/j.ecolecon.2018.02.004

Rahman, S.(2015). Agroecological, climatic, land elevation and socio-economic determinants of pesticide use at the farm level in bangladesh. Agriculture, Ecosystems and Environment, 212, 187-197. doi:10.1016/j.agee.2015.07.002

Rajendra Shrestha. P.,&Gnanavelrajah.N (2009).Assessing Biophysical and Socioeconomic Condition forWatershed Management: Case of Khlong YaiWatershed,Eastern Thailand

Rogers, E. M. (2003). Diffusion of Innovations (Fifth ed.). New York: The Free Press

Rowarth, J. S., Gillingham, A. G., Tillman, R. W., & Syers, J. K. (1992).Effect of phosphate fertiliser addition and land slope on soil phosphate fractions. New Zealand Journal of Agricultural Research, 35(3), 321-327. doi:10.1080/00288233.1992.10427509

Rushemuka, N. P., Bizoza, R. A., Mowo, J. G., & Bock, L. (2014). Farmers' soil knowledge for effective participatory integrated watershed management in rwanda: Toward soil-specific fertility management and farmers' judgmental fertilizer use. Agriculture, Ecosystems and Environment, 183, 145-159. doi:10.1016/j.agee.2013.10.020

Russell L. Lamb (1995). Off-Farm Labor Supply and Fertilizer Use

Saguye.T.S (2017). Determinants of Adoption of Sustainable Land Management(SLM) Practices among Smallholder Farmers' in JelduDistrict,West Shewa Zone, Oromia Region, Ethiopia

Seline S. Meijer, Delia Catacutan, Oluyede C. Ajayi, GudetaW.Sileshi& Maarten Nieuwenhuis (2015) .The role of knowledge, attitudes and perceptionsin the uptake of agricultural and agroforestry innovations among smallholder farmers insub-Saharan Africa, International Journal of Agricultural Sustainability, 13:1, 40-54, DOI:10.1080/14735903.2014.912493

Shepherd KD.,Soule MJ (1998) Soil fertility management in west Kenya: dynamic simulation of productivity, profitabilityand sustainability at different resource endowment levels. Agric Ecosyst Environ 71:131–145

Stoorvogel, J. J. &Smaling, E. M. (1990). Assessment of soil nutrient depletion in sub-Saharan Africa: 1983 - 2000. Report No. 28, Vol. 1 - 4. WinandStaring Centre, Wageningen, the Netherlands.

Terefe, A., & Ahmed, M.(2016). Driving force of organic fertilizer use in central rift valley of ethiopia: Independent double hurdle approach.EkonomikaPoljoprivrede, 63(4), 1265-1279. doi:10.5937/ekoPolj1604265

Thangata, P. H., &Alavalapati, J. R. R.(2003). Agroforestry adoption in southern Malawi: the case of mixed intercropping of Gliricidiasepium and maize. Agricultural Systems, 78(1), 57-71.

Tittonell. P. , A. Muriuki , K.D. Shepherd , D. Mugendi , K.C. Kaizzi , J. Okeyo , L. Verchot , R. Coe , B. Vanlauwe (2010).The diversity of rural livelihoods and their influence on soil fertility in agricultural systems of East Africa – A typology of smallholder farms

Toan, T. D., O'Keefe, S., &Crase, L. (2016). Farmer heterogeneity and water pricing reform: A case study from vietnam. International Journal of Water Resources Development, 32(6), 961-977. doi:10.1080/07900627.2015.1085368

Willey, R.W., 1979b. Intercropping _ Its importance and research needs. Part-2. Agronomy and research approaches. Field crops Abstracts, 32:73-81.

World Bank (2008).World Development Report “Agriculture for Development

ANNEXES

Representation of common agricultural inputs used in the study areas

Input types	Description	Frequency	Percentage	n
1. Control	Control (no input)	137	8.90	1539
2. Organic Fertilizer	Manure only	642	41.71	
	Compost only	27	1.75	
	Manure +Compost	80	5.19	
3. Inorganic Fertilizers	DAP+Manure	53	3.44	
	NPK+DAP+Manure	16	1.03	
	NPK+Manure	34	2.20	
	NPK+Urea+ DAP+Manure	90	5.84	
	NPK+Urea+DAP +Others+ Manure	106	6.88	
	NPK +Urea+ DAP +Manure +Compost	37	2.40	
	Urea +DAP +Manure	251	16.30	
	Urea +DAP +Manure +Compost	66	4.28	
4. Improved Seed	1.Control	137	11.29	1214
	2. Improved seeds	1077	88.71	
5. Travertine	1.Control	2335	94	2474
	2.Travertine	139	6	

Annex 4; *Bivariate representation travertine adoption with educational level*

Use of Travertine	**Education Level (n=2474)**									
	No school	%	Adult education	%	Postsecondary	%	Primary	%	Secondary	%
No	1418	**57.3**	24	**1**	**7**	**0.3**	**809**	**32.7**	**77**	**3.1**
Yes	68	**2.75**	1	**0.04**	**1**	**0.04**	**67**	**2.71**	**2**	**0.08**

Annex 5: *Bivariate representation of travertine use and farm types*

inputs	**Farm types (n=2474)**									
	1	2	3	4	5	6	7	8	9	10
No	169	171	288	313	160	186	411	212	198	232
%	6.83	6.91	11.64	12.65	6.47	7.52	16.61	8.57	8.00	9.38
Yes	3	6	10	17	9	17	14	12	16	23
%	0.12	0.24	0.40	0.69	0.36	0.69	0.57	0.49	0.65	0.93

Annex 6: Representation of agricultural inputs and land tenure

Inputs		Land tenure												
		0	1	2	3	4	5	6	7	8	9	10	11	n
Organic fertilizers	No	453	360	0	95	3	28	36	3	33	1	6	2	1539
	%	29.43	23.39	0.00	6.17	0.19	1.82	2.34	0.19	2.14	0.06	0.39	0.12	
	YES	178	247	2	67	1	6	2	1	12	0	1	1	
	%	11.57	16.05	0.13	4.35	0.06	0.39	0.13	0.06	0.78	0.00	0.06	0.06	
Inorganic fertilizers	No	189	291	1	92	4	6	2	1	16	0	1	1	
	%	12.28	18.91	0.06	5.98	0.26	0.39	0.13	0.06	1.04	0.00	0.06	0.06	
	YES	442	316	1	70	0	28	36	3	29	1	6	2	
	%	28.72	20.53	0.06	4.55	0.00	1.82	2.34	0.19	1.88	0.06	0.39	0.12	
Improved seeds	No	290	311	2	96	3	11	6	2	22	1	1	1	1214
	%	23.89	25.62	0.16	7.91	0.25	0.91	0.49	0.16	1.81	0.08	0.08	0.16	
	YES	220	149	0	36	0	17	29	2	10	0	3	0	
	%	18.12	12.27	0.00	2.97	0.00	1.40	2.39	0.16	0.82	0.00	0.25	0.00	

Hint: 0, 1, 3 Stand for owner land in rent, land owner and rent in land respectively. The rest number stands for others land tenure.

Annex 7: Bivariate representation of travertine use and land tenure

Inputs	**Land tenure (n=2474)**												
	0	1	2	3	4	5	6	7	8	9	10	11	N 2474
No	945	925	2	264	9	49	64	6	61	2	12	7	
%	38.20	37.39	0.08	10.67	0.36	1.98	2.59	0.24	2.47	0.08	0.49	0.28	
Yes	68	42	0	7	0	3	3	0	2	1	1	3	
%	2.75	1.70	0.00	0.28	0.00	0.12	0.12	0.00	0.08	0.04	0.04	0.12	

Annex 8: *Bivariate representation of travertine use and access to credit*

Use of travertine	**Access to credit (n=2474)**			
	No	**Percentage**	Yes	**Percentage**
No	1,372	**55.46**	963	**38.92**
Yes	60	**2.43**	79	**3.19**

Annex 9: representation of agricultural inputs adoption and agricultural training

Inputs		**Agricultural training**		**n**
		No	**Yes**	**1539**
Organic Fertilizers	No	336	685	
	%	**21.83**	**44.51**	
	Yes	370	148	
	%	**24.04**	**9.62**	
Inorganic Fertilizers	No	433	171	
	%	**28.14**	**11.11**	
	Yes	273	662	
	%	**17.74**	**43.01**	
Improved seedS	No	414	333	**1214**
	%	**34.10**	**27.43**	
	Yes	129	338	
	%	**10.63**	**27.84**	
Travertine	No	1105	1242	**2474**
	%	**44.66**	**50.20**	
	Yes	37	90	
	%	**1.50**	**7.41**	

Annex 10: *representation of agricultural inputs use across land forms*

Input Use	gentle	mode rate	Strong	Very strong	extre me	steep slope	Very Steep	n
Control (no input)	87	15	1	2	26	1	5	1539
percentage	**5.65**	**0.97**	**0.065**	**0.13**	**1.69**	**0.065**	**0.32**	
Organic Fertilizers	432	162	3	4	130	5	12	
percentage	28.07	10.53	0.19	0.26	8.45	0.32	0.78	
Inorganic Fertilizers	309	224	9	6	87	11	8	
percentage	20.08	14.55	0.58	0.39	5.65	0.71	0.52	
Fertilizers use %	**48.15**	**25.08**	**0.78**	**0.65**	**14.10**	**1.04**	**1.30**	
Control	87	15	1	2	26	1	5	1214
%	7.17	1.24	0.08	0.16	2.14	0.08	0.41	
Improved seed	563	292	9	8	172	12	21	
%	**46.38**	**24.05**	**0.74**	**0.66**	**14.17**	**0.99**	**1.73**	

Annex 11:Bivariate representation of travertine adoption acrross land form

Input Use	Land slope (n=2474)						
	Gentle	Moderate	Strong	Very strong	extreme	Steep slope	Very steep
No	1194	637	56	33	336	**33**	45
%	**48.26**	**25.75**	**2.26**	**1.33**	**13.58**	**1.33**	**1.82**
Yes	65	49	3	2	15	**1**	4
%	**2.63**	**1.98**	**0.12**	**0.08**	**0.61**	**0.04**	**0.16**

Annex 12: **representation of farm size of farm household**

Agricultural inputs	Land size	Frequency	Percentage	n
Inorganic &Organic Fertilizers	< 1ha	1295	84.15	1539
	1-2 ha	184	11.96	
	2-3ha	53	3.44	
	> 3ha	7	0.45	
Travertine	< 1ha	1897	76.68	2474
	1-2 ha	367	14.83	
	2-3ha	161	6.51	
	> 3ha	79	1.98	
Improved seeds	< 1ha	1015	83.61	1214
	1-2 ha	151	12.44	
	2-3ha	43	3.54	
	> 3ha	5	0.41	

Annex 15: Bivariate representation of adoption of travertine and off farm income

Use of travertine	**Off farm income (N=2474)**			
	No	**Percentage**	Yes	**Percentage**
No	1,541	**62.29**	794	**32.09**
Yes	92	**3.72**	47	**1.90**

Annex 16:Representation of agricultural inputs and livestock ownership

Inputs	Livestock Owner		n
	No	Yes	1539
Control	89	48	
percentage	**5.78**	**3.12**	
Organic Fertilizer	173	576	
Percentage	11.24	37.4269	
Inorganic Fertilizers	88	565	
percentage	5.72	36.712	
Fertilizer use in %	**16.96**	**74.14**	
Control	89	48	1214
%	**7.33**	**3.95**	
improved seed	278	799	
%	**22.91**	**65.8**	

Annex 17:Bivariate representation of adoption of travertine and livestock ownership

Use of travertine	Livestock owner (N=2474)			
	No	**Percentage**	Yes	**Percentage**
No	530	**21.42**	1,805	**72.96**
Yes	15	**0.61**	124	**5.01**

Annex 18: Bivariate representation of travertine adoption and agroforestry system

Use of travertine	Agroforestry (n=2474)			
	No	**Percentage**	Yes	**Percentage**
No	962	**38.88**	1,372	**55.46**
Yes	51	**2.06**	88	**3.56**

Annex 19:Bivariate representation of travertine adoption and irrigation practices

Use of travertine	Irrigation (N=2474)			
	No	**Percentage**	Yes	**Percentage**
No	1,862	**75.26**	473	**19.12**
Yes	107	**4.32**	32	**1.29**

Annex 20: Bivariate representation of travertine adoption and intercropping systems

Use of travertine	Intercropping (N=2474)					
	Both	**%**	Intercropping	**%**	Monoculture	**%**
No	95	**3.84**	875	**35.37**	1,365	**55.17**
Yes	3	**0.12**	40	**1.62**	96	**3.88**

Annex 21: Pearson correlation matrix of significant variables on inorganic fertilizers adoption

```
. correlate clusternumber region respondentsex farm_labour land_slope tlu land_irrigated manage_trees credit_borrowed farm_history crop_systems
(obs=1535)
```

	cluste~r	region	respon~x	farm_l~r	land_s~e	tlu	land_i~d	manage~s	credit~d	farm_h~y	crop_s~s
clusternum~r	1.0000										
region	0.0045	1.0000									
respondent~x	0.1620	-0.0347	1.0000								
farm_labour	0.0697	-0.0126	0.0192	1.0000							
land_slope	0.1409	0.1946	0.0005	-0.0226	1.0000						
tlu	0.1826	0.0099	0.0575	0.1572	0.0485	1.0000					
land_irrig~d	0.0881	0.0525	0.0574	0.0578	0.0323	0.0825	1.0000				
manage_trees	0.1432	-0.0027	0.1032	0.1511	0.0641	0.2031	0.0503	1.0000			
credit_bor~d	0.1510	-0.0856	0.0255	0.0410	0.0662	0.0537	0.0539	0.1115	1.0000		
farm_history	-0.1506	0.1397	-0.0411	0.0136	0.0009	0.0518	-0.0494	0.0865	-0.1364	1.0000	
crop_systems	0.1204	-0.0298	0.0759	0.0460	0.0263	0.0817	0.0671	0.0492	-0.0038	-0.0456	1.0000

Annex23. *Pearson correlation matrix of significant variables on travertine adoption*

	cluste~r	region	land_t~e	tlu	credit~d	ag_tra~g
clusternum~r	1.0000					
region	-0.0122	1.0000				
land_tenure	-0.0259	0.0571	1.0000			
tlu	0.1720	-0.0111	0.0110	1.0000		
credit_bor~d	0.1351	-0.1142	-0.0247	0.0734	1.0000	
ag_training	0.2361	-0.1834	0.0197	0.1306	0.2051	1.0000

Annex 24: *Pearson correlation matrix of significant variables on improved seeds adoption*

	cluste~r	region	educat~l	farm_l~r	land_i~d	ag_tra~g	credit~d	crop_s~s
clusternum~r	1.0000							
region	0.0258	1.0000						
education_~l	-0.0669	0.0075	1.0000					
farm_labour	0.0775	-0.0309	0.0819	1.0000				
land_irrig~d	0.0850	0.0486	-0.0358	0.0524	1.0000			
ag_training	0.2326	-0.1899	-0.0390	0.0423	0.1141	1.0000		
credit_bor~d	0.1582	-0.0964	-0.0215	0.0484	0.0382	0.1916	1.0000	
crop_systems	0.1338	-0.0087	-0.0242	0.0241	0.0723	0.0712	-0.0081	1.0000