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# Factors Influencing the Household Adoption of Multiple Agricultural Technologies in East Africa

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**Abstract:** This paper analyses factors that influence the adoption of multiple agricultural technology. That is: improved beans variety, biofortified maize variety, grafted fruit trees, and garden vegetable techniques in East Africa. The endogenous switching regression (ESR) framework was modeled where the farmer's choice of alternative technologies was estimated using a multinomial logit selection (MNLS) model accounting for unobserved heterogeneity. There were four major joint multiple technologies that were adopted by households in East Africa for the production of the crop that are; improved beans variety, grafted fruit trees, biofortified maize variety, and use of garden vegetables techniques. The results show that the only factor that affects the probability of adoption of the four joint multiple agricultural technology combinations apart from education level was the regional diffusion of technology in comparison to base category. A household located in the East Africa region increases the chances of adopting the four joint technology innovation by TC1 (21%), TC2 (31%), TC3 (30%), and TC4 (23%). The factors that were found to be positive and significantly influenced the adoption of a combination of three joint technologies were the education level of the household head, the general participation in community meetings, and barazas and diseases that cause problems. Given region there may be a variety of economic and political factors with different relevant agronomic characteristics that might be specific in adopting technologies. The results from the study generally conclude that theirs a potential subsistence-oriented factors that influence the adoption of multiple agricultural technologies through the link of the household's own production and, therefore recommended that more households be encouraged and influenced to embrace this factors.

**Keywords:** Household Adoption, Improved Beans Variety, Soil Carbon Management, Integrated Pest Control, Compost Manure, and East Africa

## 1. Introduction

Agricultural technologies have driven a revolution of global agricultural production since the mid-1960s [28] According to [25], substantial gains in production were achieved in Germany through greater use of improved beans variety, biofortified maize variety, grafted fruit trees, and garden vegetable techniques. This kind of technology model has been applied in East Africa, and it also contributed to growth in some situations, such as of biodiversity and soil fertility, salinization, and water [14, 7] There is established literature on how technologies affect the mean-variance of crop yield distribution, though much less is known about how technology adoption affects malnutrition [17, 21]. Previous empirical works of [13, 24] have studied the impact of single technology practices on productivity or yield and by implication on food security. The limited studies on the impact of agricultural technologies and practices such as physical conservation structures, improved seeds, crop biodiversity, production risk mitigation then to focus only on single technology adoption analysis [12, 35, 39, 38, 29, 22]).

Increasing agricultural productivity is critical to meeting the continues rising demand for food. Agricultural technologies play immense role in increasing food productivity. As a result, it is useful to examine the adoption of technologies among farmers. Agricultural technologies studied in this paper are improved beans varieties, bio-fortified maize variety, grafted fruit trees, and garden vegetable techniques. According to [26] the most common areas of technology development and promotion for crops include new varieties and management regimes; soil as well as soil fertility management; weed and pest management; irrigation and water management. According to [18] an improvement in input and output relationships, new technology tends to raise output and reduces average cost of production which in turn results in substantial gains in farm income. A study by [24] indicate that the adoption of improved technologies increase productivity, which later results in socio-economic development. Adoption of improved agricultural technologies has been associated with higher earnings and a reduction in rural poverty among farm households; improved nutritional status; lower staple food prices; increased employment opportunities as well as earnings for landless laborers. Adoption of improved technologies is believed to be a major factor in the success of the green revolution experienced by Asian countries [20]. A study by [31] show that non-adopters of agriculture technologies can hardly maintain their marginal livelihood and are more prone to socio-economic stagnation which often results in deprivation.

A combination of agricultural technology that enhances sustainable production of food is therefore critical for sustainable food security and economic development. This has made the dynamics of technical change in agriculture to be an area of intense research since the early part of twentieth century [10]. These multiple agricultural technologies are particularly relevant to smallholder farmers in East Africa countries because they are constrained in many ways, which makes them a priority for development efforts. These farmers for instance, live and farm in areas where rainfall is low and erratic, and soils tend to be infertile. In addition, infrastructure and institutions such as irrigation, input and product markets, and credit as well as extension services are poorly developed [33]. Over the years, studies have been conducted on innovation and adoption of single technologies in East Africa countries. In addition, the process of adoption and the impact of adopting single technology on smallholder farmers have been studied. However, this is not the case in the area of adoption of Multiple agricultural technologies in East Africa. This paper therefore seeks to analyze the factors that influence farmer's adoption of improved beans varieties, bio-fortified maize variety, grafted fruit trees, and garden vegetable techniques. This study determined the factors that affect the adoption of joint multi-agricultural technologies.

# 2. Empirical Estimation

The combination of descriptive and analytical techniques, combined with the other research delivery mechanisms, was used to analyze the factors influencing the East Africa household in adopting of joint multiple agricultural technologies. Various analytical techniques were used. First, the analysis involved a review of the objectives and instruments of multi-agricultural technologies on adoption [1]. Second, the linkage between the factors and technologies through a multinomial endogenous switching regression was used to establish the relationship with the factors affecting multiple agricultural technologies.

# 3. Multinomial Logistic Regression Model (MNLS)

The endogenous switching regression (ESR) framework was modeled where the farmer's choice of alternative technologies was estimated using a multinomial logit selection (MNLS) model accounting for unobserved heterogeneity. The inverse Mills ratios (IMRs) was also calculated from the estimated probabilities in the MNLS model.

Following [15] consider the latent model ($U^*_{jit}$) below which describes the i$^{th}$ farmer's behavior in adopting MATs j(j=1,….4) at time t over any alternative MATs combination,

$$. m:$$

$$U^*_{jit} = \alpha_j X_{jit} + \omega_j \bar{X}_{ji} + \varepsilon_{jit} \; with \; U \begin{cases} 1 \; if \; U^*_{jit} > max_{m\neq 1}(U^*_{mit}) or \; \tau_{1it} < 0 \\ \vdots \vdots \qquad \qquad \qquad \qquad for \; all \\ J \; if \; U^*_{jit} > max_{m\neq j}(U^*_{mit}) or \; \tau_{jit} < 0 \end{cases} \tag{1}$$

$$m \neq j$$

Where $X_{jit}$ is a vector of observed exogenous covariates that represents household and farm level characteristics, institutional support services, household assets, demographics, district dummies, plot characteristics, geographical variables and weather shocks—and α and ω are vectors of parameters to be estimated, and $\varepsilon_{jit}$ is the random error term.

The estimation of the MNLS model could be inconsistent due to correlation of unobserved factors with explanatory variables. To address this, we followed [32, 36] approach where the means $\bar{X}_{ji}$ of all time-varying covariates are included as additional covariates in the MNLS model. Unlike the adoption decision which is observable, utility derived from adoption of MATs is unobservable. Therefore, Eq. (1) entails that the ith farmer will adopt a combination of MATs j to maximize expected benefits if the technology provides greater utility than an alternative combination m, m ≠ j; e.g., if $T_{jit} = max_{m\neq 1}(U^*_{mit} - U^*_{jit}) < 0$, assuming that $\varepsilon_{jit}$ are independent and identically Gumbel distributed [2] As shown by [5], the probability that a household i at time t will choose technology j can be expressed as MNLS model with:

$$p_{jit} = \Pr(\tau_{jit} < 0 | X_{jit}) = \frac{\exp(\alpha_j X_{jit} + \omega_j \bar{X}_{ji})}{\sum^{j}_{m\neq 1} \exp(\alpha_m X_{mit} + \omega_m \bar{X}_{mi}} \tag{2}$$

Where $p_{jit}$ is the probability that individual $j$ chooses alternative $i$, $X_{mi}$ a vector of observed variables specific to individual $j$ and alternative $i$. The MNLS model structure of Eq (2) was motivated from two very different but formally equivalent perspectives. Specifically, a MNLS structure was generated from an intrinsic motivation to allow flexible substitution patterns across alternative error component structure to accommodate unobserved heterogeneity across individuals in their sensitivity to absorbed exogenous variables.

Thus, the MNLS model in Equation above was estimated using *mlogit* command in Stata Statistical Software (STATA 14).

# 4. Study Area, Data and Descriptive Statistics

It presents the comparison of means of selected variables by adoption status for the surveyed 500 households in Kenya, 500 households in Uganda, and 500 households in Tanzania. Some of these characteristics are the explanatory variables of the estimated models and will present further on. It also provides the descriptive statistics of the household adoption of technology as per social composition and household level of education.

***Table 1.*** *Description of Variables used in the Multinomial Logistic Regression Model.*

| Variable | Description | Mean | Std. Dev. |
|---|---|---|---|
| Region | 1= If household in East Africa | 0.72 | .3775063 |
| Sex head | 1= If household headed is man | 0.643 | .453735 |
| Edu head | Years | 10.388 | .7093129 |
| Size | Arable farm in acres | 3.7373 | .841117 |
| Ownership | 1= Household owned land | 0.84512 | .5995988 |
| Permanent Job | 1= If HH is employed | 0.4806 | .9745754 |
| Crop system | 1 = modern farming | 0.8696 | 2.991803 |
| Labor Agri | 1 = If family labor is available | 0.510667 | .5000529 |
| Quantity | 1 = if inputs were available | 0.823333 | .3815136 |
| Disease Control | 1 = if disease and pest control was used | 0.447333 | 1.618942 |
| Risk | 1 = if risk is positive | 0.632 | .5270533 |
| Part time Work | 1 = if casuals laborers | 0.396667 | 3.286922 |
| Ex-ed | 1= if they access extension services | 0.74343 | .64747482 |
| Irrigation | 1 = if use irrigation | 0.87 | .3364156 |
| Credit to org | 1= if member to credit organization | 0.17132 | 2.353674 |
| Food Sold | 1 = if they sell the produce | 0.167333 | .3733977 |
| Food stored | 1 = if store the farm produce | 0.5853 | .4974545 |
| Value addition | 1= if the value addition was done | 0.27263 | .53637445 |
| Group membership | 1 = if member to community groups | 0.79266 | .4055316 |
| Community Active | 1 = if member to co-operative groups | 0.85333 | .2794703 |
| Markets | Distance to Market (Km) | 2.737333 | .841117 |
| Sources: Author's own computation, 2021 | | | |

The description of variables used in the multinomial logistic regression model is shown in table 1. The mean or frequencies and standard deviation of the variable are discussed. The marginal probability measures the expected change in the likelihood of a particular choice being selected with respect to a unit of change in an independent variable. An increase in a particular characteristic variable increases the adoption rate for some technology combinations and the rate of adoption then to decrease for other technology combinations.

Most of the household (64.3%) are male-headed with an average mean level of education in terms of the number of years spent in school as 10 years. This indicate that most of the household heads are fairly educated with table 3 showing that 54.67% of the household heads attained the secondary level of education. On average 87% of the household used modern crop system technologies observing 82% of the inputs which is quite high and 87% of them utilized irrigation systems. This enabled the households to produce their products whole year round thus stabilizing supply and markets prices. In terms of productive land, the average size of arable landholding is about 3.7 acres. while, those who farm in their own land is 84.5%, this increases the household returns on investment.

Very few household (17%) can qualify for credit from the credit organization but since majority 85% are active members of co-operative societies and group membership (79%) they then to utilize this membership for their financial supports an indication of social capital among households. This has been made possible also though since 74% of the household access extension services through various platforms such as field days, farmers trainings, workshops, agricultural shows, and farm demonstrations.

Few households (16%) sell their produce direct from the farm gates while majority (59%) store their farm produce so as to sell when they have a better market (Table 1). 27% of the household practice value addition to their farm produce an indication of small scale farming among the communities. Approximately 51% of the labour in the farms were came from the household members while, 39% from the causals who work as part-time employees. This increased positively the risk of adopting technology by 63% since the drive to succeed is high for household members than the casuals. Concerning the plot characteristics, the mean distance from the nearest market to the farm was 2.8km this encouraged more households to practice farming since they could easily sell their products.

***Table 2.*** *Comparative Rate of Technology Adoption Based per Household Head.*

| Technologies | Male | Head Female | Total |
|---|---|---|---|
| Improved Beans Variety | 342 (76%) | 108 (24%) | 450 |
| Biofortified maize variety | 322 (78.92%) | 86 (21.11%) | 408 |
| Grafted fruit trees | 168 (49.41%) | 172 (50.58%) | 340 |
| Garden vegetable techniques | 148 (49%) | 154 (51%) | 302 |
| Total | 980 (65.33%) | 520 (34.67%) | 1500 |

Sources: Author's own computation, 2021

Table 2 show the rate of technology adoption of male headed household verses the household headed by a lady. Improved beans variety was the technology highly adopted with 45 percent. Since this was the entry to the joint multiple technology adoption. While integrated grafted fruit trees were the least adopted at 20.13% due to the fact that a higher level of technology is applied.

Grafted fruit trees and integrated grafted fruit trees were adopted largely by the female-headed house. The female-headed household adopted easily to garden vegetables techniques, this was possible because females are key decision-makers on household leftovers which turned to compost. According to [11] the use of manure for compost means less waste and expenses that could not strain the household since most of the female-headed household since most of the female household was a single mother household.

Grafted fruit trees is a flexible and holistic decision that appears to be made by the household head. Female-headed households adopted this technology more than the male-headed household because it entails the use of predictors of pesticide exposure which was easier for women to accept than this male counterparts [6]. 51 percent of the female-headed household adopted garden vegetable techniques. According to [9] women are more health-conscious than their male counterparts hence to prevent the negative effects of the insecticide on human health and the environment they adopted integrated grafted fruit trees also, to avoid the high cost of insecticide. It was confirmed by [16] that economic characteristics such as capital and labor also affects the female headed household in the decision to adopt integrated rest management since it is not capital and labor-intensive.

Bio fortified maize variety was largely adopted by the male-headed household at 78.92%. The technology applied is more scientific and needed high capital to achieve. [8] found out that the sustainability of carbon building soil management practices required integration of social components into research particularly from a household perspective which was more favorable for the male-headed household than their female counterparts.

According to [35] the male-headed household explored and synthesized the use of social organic carbon practices has potential gradual climate change and boosted climate-smart soil and land management practices hence building healthy soil combined with conservation and restoration. Incentives for hastening the adoption of best and emerging practices. The female-headed household had a low adoption rate on biofortified maize variety at 21.11% due to the broad range of gender interrelated enabling and constraining factors such as factor planning and implementation processes.

***Table 3.*** *The Rate of Technology Adoption as per the Level of Education.*

| Technologies | None | Primary | Secondary | Tertiary | Total |
|---|---|---|---|---|---|
| Improved Beans Variety | 30 (5.12%) | 178 (30.37%) | 320 (54.60%) | 58 (9.89%) | 586 |
| Biofortified Maize Variety | 32 (7.44%) | 146 (33.95%) | 224 (52.09%) | 28 (6.51%) | 430 |
| Grafted Fruit Trees | 20 (7.09%) | 98 (34.75%) | 156 (55.31%) | 8 (2.28%) | 282 |
| Garden Vegetable Techniques | 17 (8.41%) | 59 (29.20%) | 120 (59.40%) | 6 (2.97%) | 202 |
| Total | 99 | 481 | 820 | 100 | 1500 |

Sources: Author's own computation, 2021

Table 3 shows that the household headed by a member with no education had the least adoption rate of improved bean variety at 5.12 percent, with a household headed by a secondary school leaver leading in the adoption of improved beans variety at 54.6%. [28] in their study supported the idea that lack of education brings upon lack of adequate information about technologies, and price risks, and therefore low adoption rate to these technologies. [15] found out that many secondary school leavers in East Africa would access the internet and are mostly active in training and hence their perceived attributes of innovation that then to increase their percentage difference on the rate of adoption of technology.

Results from table 3 also noted that households headed by the secondary school leaver were leading adopters of the four technologies implemented by 52.09% in biofortified maize variety, 55.31% in grafted fruit trees, and 59.4% in garden vegetables techniques. [20] emphasized that secondary school leavers are easily reachable and generally have a high interest in farming. This enhances the understanding of instruction given and also improves the farmer's level of participation in agricultural activities. According to [6], this is so because of the training they attended and they are pro-active which enables them to access information needed to decide to use innovation and practices new technology. It also increases their managerial competence and therefore enhances their ability to diagnose, assess, comprehend, and respond to financial and production problems especially in integrated grafted fruit trees [4]. It was also noted that most of the secondary school leavers were members of co-operative societies, focus group discussion, and opinion leaders in the society, this boost their technologies adoption rate. [11] in their assessment of farmers' knowledge on garden vegetables techniques indicate that about 50 percent of farmers in East Africa utilize garden vegetables techniques since it has been an old technology and the materials were readily available [39].

A household headed by a member with tertiary education had a low adoption rate to all the technologies with improved beans variety at 9.8 percent, biofortified maize variety at 6.5 percent, grafted fruits trees at 2.28 percent, and garden vegetables techniques at 2.97 percent. These results are supported by [33] that primary school leavers are trained through hands-on experience in East Africa and are not required to have a college degree.

It was found out that household headed by a member with tertiary education was doing commercial farming instead of subsistence farming thus it was easier to use chemicals to control. They also utilize inorganic fertilizers from agro vet instead of practicing garden vegetables techniques. [28] mention that large farms are owned by the learned and wealthy cannot be considered linear replicas of small ones. Incentives to use inputs vary with production scale that is large farms use different technologies than small farms thus the use of garden vegetables techniques and integrated grafted fruit trees was low at 2.97% and 2.28% respectively because it could not fit large scale farming practice by the household headed by members with tertiary education. In agreement [20], found out that associates and bachelor's degree graduates in agricultural courses took up farming as their careers. This finding is in agreement with [27] that the relationship between the level of farmers' education with the agricultural course was positive, continuous, and significant. A similar result was also supported by [2] on their agricultural input results.

# 5. Empirical Results and Discussion

Multinomial logit regression results for factors influencing the adaption of joint MATs are presented in Table 4. There were four major joint multiple technologies that were adopted by households in East Africa for the production of the crop that are; improved beans variety, grafted fruit trees, biofortified maize variety, and use of garden vegetables techniques. At every point in time, the household made a choice of three best joint technologies to implement with a base of "no technology", this was informed by the multinomial logit model which runs the highest combinations of the technology in a household. The combinations with less than three joint technologies were analyzed however the results were not presented because it detected the issue of collinearity thus omitting some technologies the findings which supports the work of [11]. The best joint technologies are;

No TC = base with no technology used, TC1 = Joint Technology of (1,2,4), TC2 = Joint Technology of (1,2,3), TC3 = Joint Technology of (2,3,4), TC4 = Joint Technology of (1,3,4). Where, Improved beans variety =1, biofortified maize variety = 2, garden vegetable techniques= 3, grafted fruit trees = 4.

The only factor that affects the probability of adoption of the four joint multiple agricultural technology combinations apart from education level was the regional diffusion of technology in comparison to base category. A household located in the East Africa region increases the chances of adopting the four joint technology innovation by TC1 (21%), TC2 (31%), TC3 (30%), and TC4 (23%). This supports the work of [1] that regional locations diffuse certain modern technology faster if it would be congruent with the regional user behavior. This indicates that the growth of improved crop using the biofortified maize variety and garden vegetables techniques was adopted in the three East African countries of Uganda, Kenya, and Tanzania. The factors that influenced the adoption of a combination of three joint technologies were the education level of the household head, the general participation in community meetings, and barazas and diseases that cause problems. Given region there may be a variety of economic and political factors with different relevant agronomic characteristics that might be specific in adopting technologies. It supports the work of [16] that the probability of adoption of technology depends on the critical mass knowledge in agriculture within the country.

The level of education of the household head has positive effects on the probability of adoption of TC1, TC2, TC4, and TC3. A year increase of the education of household head increases the adoption of TC1 (45%), TC2 (44%), TC3 (25%), and TC4 (35%). Education level of household head has a high probability of adopting new technologies for a high level of education than those with a lower education level. The marginal effect of education on technology adoption is significantly larger and expectedly positive for improved bean crops as the level of education rise especially on the making of garden vegetables techniques. [19] found out that there is a positive correlation between the level of education and the rate of using intergraded pest control. The household in east Africa with a higher level of education than to be innovative in doing integrated grafted fruit trees and garden vegetables techniques than with households with a lower level of education. There is a positive relationship between education and the adoption of new technology.

***Table 4*** *Multinomial Logistic Regression for Factors Influencing the Joint Technology Adoption.*

| Variable | TC1 | TC2 | TC3 | TC4 |
|---|---|---|---|---|
| Region | .2146*** | .31661 *** | .292928 *** | .23959 *** |
| Sex head | .6140266 | .2391623 | .1011699 | .224311 *** |
| Edu head | .452735 *** | .444651 *** | .25488 *** | .358028 *** |
| Size | .07031 | -.0070594 | -.0151722 | .144211 *** |
| Ownership | .5515478 | .2680692 *** | .0227853 | .0198754 |
| Permanent Job | .59324 | -.0207033 | .4497901 ** | .2899868 |
| Crop system | .8802955 | -.1394908 | -.1223626 | .2748402 *** |
| Labor Agri | .289384 *** | .1498006 | -.0260566 | .2251113 |
| Quantity | -.2885715 ** | -.18956 ** | -.0022094 | -.0014606 |
| Disease Control | .1985906 ** | .2323897 *** | .2800733 *** | .1956313 |
| Risk | .0145512 | .0018817 | .11922 *** | -.020856 |
| Part time Work | .2135629 | -.0357523 | -.0404361 | -.418365 *** |
| Ex-services | .302435 *** | -.1842981 | -.4378921 | -.0509544 |
| Irrigation | .62464 | .3188364 ** | .4767842 *** | .2883762 |
| Credit to org | .3431908 | -.233378 | -.1264379 | .3182167 ** |
| Food Sold | .5596567 | .0307152 | -.1958371 | -.3637021 |
| Food stored | .5512521 | .1513067 | .3568699 ** | .3302557 |
| Value addition | -.1649092 | .4314859 *** | .3578355 | -.0592925 |
| Group membership | .526215 ** | -.4747665 | .1956892 | .2662125 |
| Community Active | .14522 *** | .189402 ** | .1632703 ** | .1114577 |
| Markets | -.32094 ** | -.2355264 ** | -.4138172 ** | -.151446 ** |
| Observations | | 3,877 | | |

Sources: Author's own computation, 2021

Standard errors in parentheses. No TC as the reference category

*** p<0.01, ** p<0.05, * p<0.1

Kluve, J., Schneider, H., Uhlendorff, A., and Zhao, Z. indicated that the years of schooling and score in a numeracy test of the household head were key variables in the ability of farmers to acquire information and adopting new technology. Fertilizer adoption is influenced more by institutional and educational factors than by economic ones [20]. Also, education is positively and significantly related to the use of improved bean varieties but not significantly related to the probability of adopting improved crop. The adoption of chemical fertilizer is positively correlated with the number of school years of the head of household. heads of households with a secondary school education adopted soil and water conservation measures as compared to that of heads with no formal education. The model developed by [25] shows that the educational level of other adult household members has an impact on fertilizer adoption than the household head level of education. Educated people perform their work and functions with higher efficiency and thus, adopt new technologies faster. Adoption studies have emphasized education as an important explanatory factor in household decision-making. It can be concluded that the accumulation of knowledge via education is an important factor for economic development.

An increase in the distance to the nearest market is associated with less likelihood of adopting all the four technology combinations. The results further indicate that 1 km increase in the distance to markets the household adoption of TC1, TC2, TC3, and TC4 likely reduces by 32%, 23%, 41%, and 15% respectively. This finding resonate with some researches who found that excessive distance to markets negatively impact on adoption of technology such as inputs. The household who had distance constraining them will thus end up using low yielding unimproved and retained seeds. An increase in distance to output market means access to market is inconvenient, the household then to have post-harvest loss and thus reducing the nutritional content of their produce. when a household member participates in group markets like buying improved crop and equipment for preparing garden vegetables techniques there is a positive adopting joint technology since they will make informed decisions. [32] explain that markets and externalists could be major barriers to technology adoption but these inefficiencies can be overcome through farmers' groups which is key to boosting agricultural information dissemination knowledge of markets and pricing as a result it increases the adoption of technologies and improved yields.

Results show that the adoption of disease control methods is positively related to TC1, TC2, and TC3. A season management of diseases and pest by the household leads to adoption of TC1 (19%), TC2 (23%), and TC3 (28%). Availability of diseases outbreaks management leads to households adopting improved beans variety, garden vegetables techniques, and integrated grafted fruit trees so as to control these problems. Technology adoption is essential in disease control in that high susceptibility of logical landraces to pests and diseases on improved beans variety among smallholder farmers encouraged them to adopt the integrated grafted fruit trees methods.

Household member participation in community meetings and barazas positively increases the adoption of TC1, TC2, and TC3 by 14%, 19% and 16% respectively. This indicates that the drives of the community and the leaders of society have helped to push down the idea of community empowerment through technology thus the members than to follow their lead. Household members who participate in the meetings then to benefit from Improved beans variety distributed in the meetings and the various lessons of making garden vegetables techniques. Community meetings the information on technology, especially on biofortified maize variety and garden vegetable techniques, is freely shared leading to trust and confidence in the adoption of this technology by members. The meetings also facilitate the networking and learning process since the members than to have a more direct role in both initiating and design of the technology implementation [31]

A positive and significant effect of membership to any group or organization on TC1 indicates that the household increased the adoption by 52% and organizations are mainly on the farmer's sanitization programs and community developments on the importance and use of improved beans variety and garden vegetable techniques. [28] in his study concluded that extension access and organizational membership have a strong effect on the use of biofortified maize variety and garden vegetables techniques on planting improved crop in that the membership in local groups and organizations attitude towards the technology is advance affected. Results also show that household whose member's participated in general community meetings had a positive significant impact on joint TC3 by 52%, hence indicate that community network ties are generally consequential because friends and members are often viewed as convenient and trustworthy sources of information thus teaches and encourages the participants on the utilization of soil garden vegetables techniques and integrated grafted fruit trees on the production of improved beans variety. when a household member has membership in any savings or credit organization the probability of adopting technology combination TC4 is more likely at 31%. This will help the household with funds to buy improved beans variety and implement integrated grafted fruit trees since they will not have financial constraints.

A positive and significant effect of family labor on TC1 indicates that when a household member is involved in farm labor the adoption of Improved beans variety, biofortified maize variety, and garden vegetables techniques is more likely to increase by 29%. [29] explains that this is fundamental to the advancement of the agricultural industry, labor savings, and household members could provide the leadership from within the adoption and raise the standards of influence on the adoption especially on garden vegetables techniques and biofortified maize variety. It supports the conclusion of [22] that shortages of family labor have been used to explain the non-adoption of technology in Africa; meanwhile, the higher rural labor supply has been associated with greater levels of adoption of labor-intensive rice varieties in Taiwan. Additionally, hired labor positively affects TC1. Professional labor could ensure the right procedure and utilization of garden vegetables techniques and biofortified maize variety and the right variety of the improved crop. The skill upgrading and the adoption of technologies have altered the production and sufficient diffusion of multiple technologies in rural households.

However, technology generally requires more labor inputs, and so labor shortages may prevent adoption. Labor availability is often mentioned as a variable affecting farmers' decisions of adopting new agricultural practices or inputs. Some new technologies are relatively labor-saving, while others are labor-intensive. A serious shortage of labor will motivate landowners to adopt new technologies. When local labor markets are functioning properly, farmers can hire labour as needed. When these markets are not functional, households must supply their own labour for farm activities, and so they may choose not to adopt technologies that would require more labour at any specific time than the household can provide. Therefore, a farm household with a large number of active members is more likely to be in a position to test and then adopt potentially profitable new technology.

Results also shows that a household with a permanently employed member is positively significant to the adoption of TC3 hence when a member of the household gets a permanent job they will increase the chances of adopting joint TC3 by 45%. [31] using the endogenous treatment effect model to account for selection bias on household technology adoption decision found out that permanent employment to a member of a house had a positive and significant effect on the use of biofortified maize variety and garden vegetable techniques. Employment choices and opportunities have changed the way households regard technological innovations and their adoption.

Whereas, part-time labor was found to have negative and significant impact on the adoption of TC4 (42%). This means that when household employ farm causals on part time basis the adoption of technology combination TC4 reduces by 42% since part-time workers in the farm does not give the household a chance to take total control of their technology adoption especially the garden vegetable techniques. The adoption rates of improved beans variety are low and the implementation of joint technologies remains poor since the household has less time to implement innovations [35]

Adoption of TC1 and TC2 is negatively related to the quantity of crop variety planted per season by 29% and 19% respectively. The adoption of technologies at the farm level is more on the quality than the quantity. The quantity can be an obstacle that prevents the uptake of technology of soil carbon and garden vegetables techniques since the increase of the improved crop should be accompanied by the increase in the other two technology combinations. More so, the more the quantity of crop planted the less adoption of joint improved crop, biofortified maize variety, and garden vegetable techniques. [30] explains that when a household increases the quantity of crops planted there should also be a significant increase in farming size to accommodate better technology otherwise it will have a negative impact.

The land ownership is positively significant affecting households who adopt the joint TC2 technology by 27% since it's been hypothesized that the land ownership encourages agricultural technology adoption especially biofortified maize variety and garden vegetable techniques.

The biofortified maize variety technology has a profound impact on land ownership with a print title since the household than to make long term decision. Many empirical studies have focused on the link between land ownership and access to credit, as ownership of land is often thought to be a prerequisite for obtaining credit [23] have established the difference in economic performance between titled and untitled farmers. Per unit of used land, titled farmers invest more inland, use more inputs, and generate higher levels of output than untitled farmers. It is generally held that tenants of farmland are less likely to invest in conservation practices and households with borrowed and rented land do not apply any measures to their fields. However, tenants are more likely to use conservation tillage than full owners. Land ownership increases the likelihood of using soil protection measures in general and that land security is positively and significantly associated with hedgerow adoption in particular. [24] has shown that investment in water supply for maize production is influenced by the deeds of land tenure in western Africa. Land registration enhances tenure security and land titles improve economic performance mostly by facilitating access to institutional credit. Furthermore, insecurity of land tenure increases the risks for farmers and, may decrease their adoption of new technologies.

Land size positively affects the adoption of joint TC4 (14%) it confirms that slowing growth rates on-farm technology adoption especially integrated grafted fruit trees and improved variety are coupled by limited lands. It brings farm inefficiencies and economic constant therefore it concluded that the size of the plot cultivated by the household is positively significant to joint adoption of technologies. Empirical studies have consistently provided that farm size represented by land area then to be significantly related to the adoption of multiple joint technologies. A small farm size impedes the efficient use of improved crop and the adoption of garden vegetables techniques. [20] have illustrated that farm size significantly and positively influences the adoption of improved beans variety in a study conducted in Kenya. There is a positive relationship between the adoption of multiple technologies and farm size in southern Uganda. Though, there is a limit to the positive relationship between farm size and joint technology adoption. The adoption of grafted fruit trees and garden vegetables techniques on farms in Tanzania increased with farm size up to one hectare, then the size was no longer significant.

The results show that irrigation whether by traditional means or modern means positively enhances the adoption of TC1 (31%) and TC2 (47%). The implications of irrigations have the essence of biofortified maize variety technology thus conserving water for improved beans variety. The widespread irrigation of low-water volume reduces the biofortified maize variety and lessen the expenses of grafted fruit trees hence encouraging households to adopt the joint technology.

The household decision to store crop before selling in order to fetch higher prices had a positive significant influence on the adoption of joint TC3 (35%) as the integrated grafted fruit trees technology helps households to store their improved beans variety for a long time without being destroyed by pest and diseases.

Value addition on the processing of the crop is positively significant on joint TC2 indicating that households were willing to adopt the technology by 43% due to the idea of value addition. The household could increase the use of garden vegetables techniques, Improved beans variety, and biofortified maize variety since they knew they could do value addition of their products hence earning bigger and better income and nutritional value. [32] explains that the value addition has a strong effect on household adoption of technologies because the decision goes beyond the food consumption to the impact in the nutrition of the household that results from the food they produced and process.

Risk perception and risk attitude are positively significant to the adoption of TC3 (11%) technology hence averting risks that to leads the decision-maker to diversify to reduce income risk, especially in the absence of economies of scale. [18] found a positive but non-significant effect of averting risk for Tanzania farmers concerning the adoption of grafted fruit trees and manure technology. Risks are mostly involved in joint technology being introduced then to be more uncertain with multiple technologies. Risk perception is an endogenous factor, so the implications of risk in terms of farmer decisions then to change if the attitude, perceptions, and influence of farmers change. Attitude and perceptions of risk related to multiple technologies diminish over time through the acquisition of interest, experience, and information.

There is a significant and positive relationship for a household headed by a man in adopting the joint technology TC4 faster than a household headed by a woman by 22%. In East Africa, the fundamental role for production and access to an improved variety and technological innovations are edged for a man. More so, technologies like biofortified maize variety and garden vegetables techniques preparation are not designed considering women's needs and conditions.

Crop cropping system is positively significant to the adoption of joint technology TC4 hence the change of cropping system by the household from the traditional to modern methods increase by 27% the chances adoption of joint TC4. [2] explains that improved crop change has been the basis for increasing agricultural productivity and promoting a new farming system by generating integrated grafted fruit trees technologies that are appropriate for farmer's circumstances.

Analyzing the results revealed that the frequency of contact with extension services increases the likelihood of technology bundle TC1 adoption. Household who receives the extension services is likely to increase the adoption of TC1 by 30%. This is explained by the fact that most household got the opportunity to practice improved beans variety, biofortified maize variety, and garden vegetable techniques in their home gardens hence more convenient.

## 6. Conclusion

It's concluded that the factors of production such as region, education level of household head, land ownership, quality of crop planted per season, control of diseases that caused problems to crop production, irrigation of crop crops, value addition and the processing of crop, household members who participate in general community meetings and workshops are identified as the key determinants to multiple agricultural technology adoption. The results from the study generally conclude that theirs a potential subsistence-oriented factors that influence the adoption of multiple agricultural technologies through the link of the household's own production.

## 7. Recommendation

Since the geographical location plays to the advantage of the household for the four joint technology of TC1, TC2, TC3, and TC4 within East Africa it's therefore recommended that more households be encouraged and influenced to adopt multiple technologies. The policy should be put in place to allow the household in East Africa to practice more than one technology application. Household members within East Arica are recommended to participate in the credit and savings organizations and also get involved in the group market strategies as it will encourage the maximum benefits of the joint multiple agricultural technologies. Households are recommended to encourage their members to increase their education level since it affects the uptake of joint technology. This will increase the chances of households making an informed decision on technology utilization. Local governments are advised to provide alternative methods, mechanisms, and support programs for controlling diseases. Pests and diseases pose a serious risk for production and technology adoption. It is also recommended that the household should follow the guide on the number of crop per space given so as to maximize the technology adoption.

The household is recommended to hire professional labor to oversee technology adoption. This then to ensure the right procedure are followed in the farm and can help in making the informed decision when calling upon. The agricultural extension officers are encouraged to organize frequent community meetings and barazas since the members learn from these meetings about the different methods of implementing joint technology. The government is recommended to provide title deeds and land ownership documents to the households. The household with land ownership than to make long term goals and plans thus affecting the joint technology adoption.

It is also recommended that an irrigation system should be set up across the farms in East Africa. Policymakers and local leaders should mobilize for resource allocation to reach more farmers with irrigation kids and water supply. More processing industries and well-equipped storage facilities should be constructed to support the household in value addition. This will lead to higher adoption of multiple technologies as the household will be expecting better returns. It is recommended that the farmers should follow the right cropping system so as to utilize the multiple agricultural technologies in an appropriate way. Household members are encouraged to work on the farms on a full-time basis rather than part-time. The household members working on a part-time basis have a negative impact on multiple technology adoption.

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