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Research Article

Determinants of Climate-Smart Practice Adoption Among Smallholder Farmers in West Pokot County, Kenya: A Multivariate Probit Analysis

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Abstract

Climate variability poses a serious challenge to smallholder farmers' lowering agricultural productivity, decreasing the rate of adoption of climate-smart practices despite the increasing importance for sustainable and resilient farming production systems. Adoption rates of most climate-smart practices is still, and uneven distributed. Factors influencing smallholder farmers' decision to adopt various practices are not fully exploited in specific locations. This study evaluates the adoption of selected climate-smart practices and their related determinants amongst smallholder farmers in West Pokot County, Kenya. Data was collected amongst 390 smallholder farmers using a multistage sampling technique and analyzed using multivariate probit model. Results showed variations in adoption rates across the selected climate-smart practices with agroforestry recording the highest adoption rate (48.21%), followed by drought-tolerant crop varieties (46.15%), green manure (23.59%), organic fertilizer (20.26%) and irrigation (10.26%). Crop diversification positively influencing adoption of agroforestry, drought-tolerant crop varieties, organic fertilizer and green manure, while negatively associated with adoption of irrigation. The age of the household head and farm size positively influenced agroforestry and organic manure adoption, while access to extension services had a positive association with adoption of irrigation. Perceived plot soil fertility positively influences adoption of drought-tolerant crop varieties and green manure use, while perceived plot soil infertility negatively influence agroforestry and irrigation adoption. Use of indigenous knowledge positively influence adoption of drought tolerant crop varieties and had a negative correlation with adoption of agroforestry and green manure application. Membership to farmer groups positively influences adoption of organic fertilizer, while gender of the household head, off-farm income and access to credit had a negative association with adoption organic fertilizer. Results highlight heterogeneous adoption of climate-smart practices and the relevance of accounting for variations in household characteristics, institutional support services, and farm-level factors. The study provides empirical evidence to guide targeted extension services, soil fertility management and locally suitable agricultural technologies to enhance climate-smart practices adoption and strengthening sustainable production systems, household livelihood and resilient of smallholder farming systems in West Pokot County, Kenya.

Keywords

Determinants, Climate-Smart Practices, Adoption Decisions, Smallholder Farmers, Multivariate Probit, Agricultural Biodiversity Conservation, West Pokot, Kenya

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1. Introduction

In Sub-Saharan Africa, smallholder farming system is increasingly constrained by climate change, soil fertility degradation, water scarcity and growing need for sustainable agricultural production system under rising uncertain weather conditions. Majority of rural households are affected by these above challenges as most of them depend on climate-sensitive agricultural practices and have limited ability to tolerate production shocks [1, 2] However, climate-sensitive agricultural activities have gained attention as a common pathway for sustainable farm productivity, strengthening adaptive capacity, and decreasing vulnerability of rural household livelihoods to climate shocks. The potential gains of adoption of climate-smart practices depends not only on their technical efficiency but also whether the farmers household have access, can afford and integrate the climate-smart practices into current production systems [1, 3]. Accordingly, understanding the determinants of adoption of climate-smart practices is critical for designing agricultural interventions that are both locally accepted and able to reach resource constrained smallholder farmers.

Main characteristic of climate-resilient agriculture is that adaptation depends multiple agricultural intervention. Farmers normally adopt a combination of agricultural practices that address numerous and related production challenges. Adoption of agroforestry may be mainly integrating trees into agricultural landscapes, mainly for supporting soil conservation, micronutrient control and diversified farm output, but benefits of adoption of agroforestry depend mainly on tree species planted, management practices used and local environmental conditions [4]. Adoption of drought tolerant crop varieties decrease exposure to moisture stress, but its effectiveness, performance and benefits depends majorly on crop varieties characteristics and environmental conditions [5]. Whereas irrigation adoption decreases dependency on rain-fed agriculture through giving greater control over crop water availability [6]. Use of organic fertilizer improves soil nutrient, manages soil fertility and contributes to soil nutrient organic matter [7]. Therefore, these climate-smart practices operate through various techniques, while adoption may be interrelated due to competition for complementary use of land, capital, labor, water, and management production resources. The important policy issue is not simply whether a farmer adopts single practices, but also what determines the selection amongst potentially complementary adoption alternatives.

Past empirical research evidence conducted by various scholars supports the importance of investigating adoption as a multidimensional decision-making process. For instant, a study conducted in Western Kenya instantaneously analyzed the adoption of various climate-smart practices such as agroforestry, use of animal manure, crop diversification, crop livestock integration, soil and water conservation using a multivariate probit model and ordered probit [8, 9]. Results suggest that farmers household characteristics, extension visits, access to agro-weather information, farm resources endowment and perception of the environmental challenges and interdependence amongst practices influence adoption decision these practices [8, 9]. Another study conducted in Kenya's Nyando basin concluded that household savings influences adoption of climate-smart agricultural technologies demonstrating the potential significance of financial resources in influencing smallholder farmers capacity to invest in adaptation [10]. The findings from these researchers revealed that adoption of agricultural practices is influenced by a combination of household resources, demographic, socioeconomic, institutional factors and interconnection amongst agricultural practices rather than by the availability of the technology alone [8-10].

This study examines factors influencing adoption of selected five climate-smart practices such as agroforestry, use of drought tolerance variety, use of organic manure and application of irrigation. There is distinct scope in adoption of various agricultural practices, thus supporting joint investigation of determinants of adoption. Agroforestry as a climate-smart practice allows land-management pathways by which trees are integrated with crops and other farming practices. Planting of drought tolerance crop varieties offers a crop-based response to moisture stress, perceived variety performance and visibility of drought tolerance traits. Past research conducted in Kenya revealed that drought-tolerant maize variety performs better with high yield without farmers necessarily perceiving it as a more drought tolerant. This undermines the importance of information and training in adoption decisions of smallholder farmers [5]. Use of Irrigation in the farm reported variations in adaptation pathways because it entails access to water, ability to finance and manage water infrastructure. Previous research conducted in Kenya on dryland have demonstrated the critical role of irrigation in agricultural adaptation amongst transitioning pastoralist and agro pastoral communities [11]. Furthermore, subsequent work on farmer-led irrigation development has emphasized the relevance of recognizing locally initiated irrigation investments in agricultural planning [6]. Organic fertilizer utilization depends on the availability of compost, availability of livestock to produce manure, transportation costs, labor availability and farmers' knowledge on soil fertility management [7, 12]. The variations suggest that factors associated with one practice may not influence adoption of other practices. Thus, investigating determinants of adoption of the selected climate-smart practices jointly can give more nuanced understanding of farmer adaptation decisions that focus on individual practices [8].

In Kenya, there is need to investigate factors influencing smallholder farmers decision to adopt various agricultural practices. Most of the smallholder farmers reside in localities with diverse environments and farmers differ in terms of ac-

cessing agricultural resources, information and access to markets [13]. Previous studies have investigated the adoption of climate-resilient and climate-smart agricultural technologies in various regions contributing context-specific evidence. In Kenya studies conducted evaluates a joint adoption of the practices in Western Kenya, but in upper and central Kenya studies only focus on awareness and adoption of climate-resilient agricultural practices [8, 13]. The findings from these studies give useful insights on adoption behaviors of smallholder farmers, but evidence from one region cannot be used for generalization other locations with different environmental conditions. Variations of farming systems, agroecological conditions, access to institutional support services, production constraints and household resource ownership influence the choice of various agricultural practices. Therefore, evidence from West Pokot County was useful for revealing important factors influencing adoption of selected climate-smart practices for a given smallholder farmers context [9, 13].

West Pokot County offers important setting for examining the decision of smallholder production decisions and choices that must be understood in terms of local agroecological conditions, resource endowment and access to institutional support services. The relative feasibility of agroforestry, drought-tolerant varieties, irrigation and organic manure adoption may differ depending on farm household resources, farm-level characteristics and access to institutional support services. But previous findings from studies conducted in Kenya do not necessarily identify which factors were most strongly linked with adoption in West Pokot [8, 13]. County-specific empirical research evidence is required to determine whether similar household and institutional factors influence adoption of the four selected climate-smart practices or whether their influences vary according to resource owned and management practices required for a specific practice.

Moreover, despite the rising need for sustainable farming practices and agricultural diversification in ASAL areas, little is known about factors influencing adoption and interdependence amongst climate-smart practices amongst smallholder farmers in West Pokot County, Kenya. Thus, there is need for context-specific empirical evidence that examined multiple climate-smart practices jointly and relevant factors influencing the individual adoption decision amongst smallholder farmers. Also existing empirical research mainly examines climate-smart agricultural technologies, conservation agriculture and independent agricultural technologies other than explicitly investigating the adoption of climate-smart practices as a separate analytical framework [1, 3]. Filling this gap enables improving the understanding of farmer characteristics, household resource endowment, market access and institutional factors in influencing various patterns of adoption of agricultural practices. It allows determination on which agricultural intervention adoption to focus on individual or consider a package of climate-smart practices that smallholder farmers may adopt concurrently [14]. These evaluations are essential in designing relevant policy interventions that consider smallholder farmers varying resources constraints and potential interactions amongst agricultural practices.

This study investigates the determinants of adoption of selected climate-smart practices amongst smallholder farmers in West Pokot County, Kenya. Therefore, the study examines the relationship between farmers demographics, socio-economic, farm-level resources, market access and institutional factors influencing farmers' decisions to adopt climate-smart practices while accounting for potential correlations amongst various decisions. The study used a multivariate probit model to estimate the adoption equations jointly and assess the correlations between unobservable traits. The study findings contribute to stock of knowledge by providing context-specific empirical evidence on factors influencing adoption of various selected climate-smart practices and investigating the extent to which adoption decisions are interrelated. Results informed more integrated and locally responsive agricultural interventions that support agricultural sustainability and agricultural diversification amongst smallholder farmers' production systems.

2. Literature Review

Empirical studies conducted in Africa countries confirms the argument that adoption decision of climate-smart agricultural technologies depends on local agroecological conditions and farmers usually adopt multiple practices jointly. A study conducted in Ethiopia to investigate adoption of multiple climate-smart agricultural practices amongst smallholder farmers applying multivariate probit model, practices under consideration were crop diversification, use of irrigation, early maturity crop varieties, integrated soil fertility management, integrated pest control and drought-tolerant varieties. Results showed that adoption decisions were interdependent and differ amongst various farmer and agroecological locations [15]. This is important for this study as it illustrates the value of evaluating multiple adoption practices jointly rather than treating each as a separate decision. Another study used similar method to evaluate adoption of multiple climate-smart agricultural practices such as conservation agriculture, irrigation, agroforestry, crop diversification, and integrated soil fertility management. Adoption of these practices was found to be strongly influenced by farm size owned, training received, receipt of extension services access, received of credit, livestock ownership and farm household characteristics [16]. Study recommended the essential to promote appropriate practices in each agroecological region. Adoption of the practices were found not to be influenced by individual single set factors but the importance of evaluating individual practice as determinants of adoption decision vary across practices, farmers and environmental conditions [16]. Other studies conducted in ASAL areas on agroforestry-based crop management using similar approaches to determine farmers' joint decisions concerning different agricultural practices to understand how

farm-management selection interact under resources constraints and climate risks [17, 18]. A study conducted in Tanzania using MVP to investigate adoption of climate-smart technologies such as crop diversification, livestock diversification, irrigation use, application of fertilizer and agroforestry. The study identifies both trade-offs and complementarities between practices with farm household resources and control for farm resources influencing adoption [17, 18].

Consequently, international studies determine adoption of multiple practices using different approaches. Therefore, results from crop-based system in Tanzania or Ethiopia cannot be generalized for conclusive of West Pokot County without accounting for potential variations in agroecological conditions, production systems, household resources ownership and access for institutional support services. Furthermore, the research included practices such as agroforestry, use of irrigation, drought-tolerant varieties, soil fertility management, thus the studies does not determine the same four climate-smart practices as a single adoption system in the Kenyan context. Adoption of climate-smart and climate-resilient agricultural practices in Kenya such as use of irrigation, organic fertilizer, drought tolerant varieties and agroforestry are promoted to enhance climate risks, strengthen household resilience, increase farm productivity, and improve sustainable agricultural production [2, 3, 9]. Adoption rate is influenced by farmer household characteristics, demographic factors, socioeconomic factors, household resources, farm-level factors, access to institutional support services, access to weather information and agroecological conditions [8, 13, 19, 20]. In addition, personal factors, farm-level characteristics, financial, environmental and information access influence uptake of climate-smart agricultural technologies [3]. Access to agricultural extension services, training, access to credit, membership to farm base-organization and access to weather information promote adoption of agricultural practices, but constraint and limited access to resources and institutional support services limits farmers' ability to utilize agricultural practices [19, 21]. Results demonstrate the relevance of determining adoption within specific agroecological and socioeconomic contexts rather than assuming similar factors influence adoption various agricultural practices in similar manner.

Another study evaluates determinants of awareness and adoption of climate-smart agricultural practices to provide the importance of understanding awareness and the actual adoption status [13]. Other research determines factors influencing adoption and the extent of adoption of climate-smart agricultural technologies in Kenya [22]. Factors found to significantly influence smallholder farmers' decision whether to adopt or not adopt a given climate-smart agricultural technologies were land ownership, access to credit, farm asset ownership, membership farmer-based organization, household income, and experience in farming. Besides, financial constraints, poverty, and limited access to credit contribute to low utilization of climate-smart practices amongst smallholder farmers [8, 23]. Results display promoting technologies through awareness and training alone may be inadequate when farmers lack agricultural production resources required for implementation of agricultural practices. Despite the existing literature on adoption of climate-smart technologies further context-specific studies are warranted. Previous research conducted in Kenya investigated various combinations of agricultural practices and farming agroecological conditions, but determinants of adoption of agroforestry, drought-tolerant crop varieties, use of irrigation and organic fertilizer adopted jointly remain inadequate identified for specific-context of West Pokot County. This is useful because these climate-smart practices vary in terms of resources requirements, labor, capital investment, land size, and farmer knowledge. Thus, smallholder farmers' decision to adopt a give climate-smart practice differs across practices within the same household.

Previous literature review demonstrates various research gaps that this study tends to address. First gaps is geographical research gaps where most studies conducted in Kenya mainly focus on evaluation of factors influencing adoption of climate-smart and climate-resilient agricultural practices in western, central, Easter and other parts of the country, but limited research on the determinants of adoption of selected climate-smart practices in West Pokot County that requires context-specific evaluation. Transferring the results across regions is constraints by variations in rainfall patterns, farming systems, water and land availability, household asset ownership, and access to institutional support services. Another is a practice-specific and conceptual gap as most of the previous literature focuses on a wider range of climate-smart agriculture, climate-resilient agriculture and sustainable land management practices. The frameworks are important but factors influencing adoption may vary across agroforestry, drought-tolerant crop varieties, use of irrigation and organic fertilizer as each practice requires distinctive resources and gives various benefits. Thus, examining these practices simultaneously enables establishing whether their adoption decisions had a common determinant to different farm household and institutional factors. Lastly, is the methodology gaps as previous studies applies multivariate probit model to illustrate that multiple adoption decisions are interdependent, but determinants and associations determined in other locations may not hold in West Pokot County. Use of analytical methods such as MVP for the selected climate-smart practices enable this study to evaluate their adoption equations jointly while addressing correlations between unobservable factors influencing adoption decisions of smallholder farmers. Besides, to determine whether adoption decisions are statistically significantly linked and established causal substitute or complimentarily. Therefore, this study contributes to geographically specific and practice-specific evidence on demographics, socioeconomic, farm-level and institutional factors influencing adoption of agroforestry, drought-tolerant crop varieties, irrigation, and organic fertilizer use amongst smallholder farmers in West Pokot County, Kenya.

3. Methodology

3.1. Study Area

The study was conducted in West Pokot County located in Kenya former Rift valley province that borders Turkana County to the north, Baringo to the East, Elgeyo-Marakwet and Trans Nzoia counties to the south and Uganda to the West. West Pokot County covers approximately 9,123.2 km^2 and has a population of 621,241 [24]. The county has a diverse topology and produces substantial climatic variations, with an average annual rainfall ranging from approximately 400 mm in the lowlands to 1,500 mm in highlands, with a mean annual average temperature ranging between 10°C to 3°C [25]. Rainfall had a bimodal pattern with main season rains occurs between March to June and short season rains occur between September towards November. Agroecological conditions in the county, attached to recurrent droughts, land degradation, and limited agricultural productivity create challenges for food security and household livelihoods [25, 26] Therefore, West Pokot County offers a better location for determining factors influencing smallholder farmers' adoption of agroforestry, drought-tolerant crop varieties, application of irrigation and use of organic manure.

3.2. Sampling Procedure

The study used a multistage sampling technique to select smallholder farmers in West, Pokot County, Kenya. In the first stage, West Pokot County was purposively selected based on diverse agroecological conditions, high vulnerability to climate shocks, recurrent droughts, floods, water scarcity high food insecurity, and complicated geographical status. In the second stage, North Pokot Sub-County was purposively selected amongst the four sub-counties of Kapenguria, Central Pokot, North Pokot and South Pokot. The sub-county was selected based on fragile ecological conditions and pronounced vulnerability to frequent droughts and climate-related shocks. In the third stage, Suam, Riwo, Weiwei and Chepareria wards were selected from North Pokot Sub-County. These wards were selected based on high concentration of smallholder farmers and important of agricultural production under diverse and fragile environmental conditions. In the last stage, lists of smallholder farmers were obtained from ward agricultural extension officer and used as the sampling frame. The required sample was then proportionately allocated amongst the selected wards as per the number of eligible smallholder farmers in each ward. In each ward sampled smallholder farmers were selected using simple random sampling methods from relevant lists provided by the ward extension officers. This procedure ensured that each eligible farmer from the selected wards had a known and non-zero probability of being selected in the study.

3.3. Sample Determination

The target population consists of smallholder farmers from the four wards from North Pokot Sub-County with a population of 78,945 households [24]. The sample size was computed using proportion sample size formula by [27] as the population was not known by certainty.

$$n = \frac{z^2 pq}{d^2}$$

where, n is the required sample size, z is standard normal deviate at 95% confidence level, p is the percentage picking a choice, q is 1−p which is the proportion of population with measuring the characteristics, d is the allowable error (0.0496) thus,

$$n = \frac{(1.96^2)(0.5)(1-0.5)}{(0.0496)^2} = 390.38$$

n=390

Accordingly, the study targets a sample of 390 smallholder farmers households. The sample was distributed as shown in Table 1 below based on proportionate sampling size. This distribution provides coverage of the selected study locations and facilitates the collection of household-level data on adoption of agricultural practices and their relevant determinant factors.

Table 1. *Sample size Distribution per Ward.*

Strata	Population	Sample proportion	Sample
Suam	15,338	0.1943	76
Riwo	26,660	0.3377	132
Weiwei	14,840	0.1880	73
Chepareria	22,108	0.2800	109
Total	78,946		390

3.3. Data Collection

The study relied on primary household-level data collected from smallholder farmers in the selected wards in Wester Pokot County, Kenya on 2024 production year. Data were collected using semi-structured questionnaires programmed in Open Data Kit (ODK) application administered to the household with a team of well-trained enumerators using face-to-face interviews. Prior to actual data collection, the questionnaire was pre-tested using a pilot study involving 38 smallholder farmers in Central Pokot subcounty since it has contrasting agroecological characteristics and agricultural production conditions that offers useful context for evaluating the suitability of the questionnaire for the study. Reliability test was conducted and Cronbach Alpha with a coefficient of 0.78, exceeding the commonly accepted minimum threshold of 0.70, indicating accepted internal consistency reliability. The questionnaire was revised and considered suitable for data collection.

3.4. Analytical Framework

Households' decisions to adopt selected climate-smart practices are interdependent, the selection of a single type of climate-smart practice could influence the selection of another practice, and this supports the need to estimate them jointly. This means that there could be correlations among binary responses of multiple practices and interdependencies among climate-smart practices and decisions. To achieve this objective, Multivariate Probit (MVP) was used to allow jointly modelling of the adoption of selected multiple climate-smart practices and determinants of adoption of climate-smart by controlling for the error term to be freely correlated. Majority of farmers adopted multiple climate-smart practices rather than individual practice. Therefore, the MVP model allowed evaluation whether there were complementarity (positive correlation) and substitutability (negative correlation) among adopted climate-smart practices, thus providing a more comprehensive understanding of determinants of adoption of climate-smart practices [28]. The typical empirical specification for the MVP model was as shown in equation (1) below.

$$Y_{ij}^{*} = X_{ij} \ \ \beta_j + U_{ij} \qquad (1)$$

where $j = Y_1 \ , Y_2, Y_3, Y_4, Y_5$ denotes the climate-smart practices binary choices in the study, namely: Agroforestry systems, planting drought-tolerant varieties, irrigation, use of organic fertilizers, and Cover crops/ green manures. From Equation (2), the assumption is that a rational i^{th} farmer $i = 1, \ldots, n$ has a latent variable Y_{ij}^{*} which captures the unobserved preferences or demand associated with the j^{th} choice of climate-smart practices. This latent variable is assumed to be a linear combination of observed characteristics X_{ij} that is the farmer, socioeconomic, institutional, and agroecological factors affecting the adoption of j^{th} practices, as well as unobserved characteristics captured by the stochastic error term. U_{ij} The vector of parameters to be estimated is denoted by β_j Given the latent nature of Y_{ij}^{*}, the estimations are based on observable binary discrete variables Y_{ij} , which indicate whether a farmer adopts AGB practice or not. Using the indicator function, the unobserved preferences in Equation (2) translate into the observed binary outcome equation for each choice as follows:

$$Y_{ij} = \begin{cases} 1 & if \ \ Y_{ij}^{*} > 0 \\ 0 & otherwise \end{cases} \qquad (2)$$

Since adoption of multiple practices is possible, error terms in Equation (2) jointly follow a multivariate normal distribution, with zero conditional mean and variance normalized to unity, where $U_{ij \sim MVN}$ (0, Σ) and the covariance matrix Σ is given by.

$$\begin{pmatrix} U_{1i} \\ U_{2i} \\ . \\ . \\ U_{ni} \end{pmatrix} \sim \begin{bmatrix} 1 & p_{12} & p_{1n} \\ p_{21} & 1 & p_{23} \\ p_{n1} & p_{n2} & 1 \end{bmatrix} \qquad (3)$$

This assumption means that Equation (2) will give an MVP model that jointly represents decisions to adopt practice. This specification with non-zero off-diagonal elements allow for correlation across the error terms of several latent equations, which represent unobserved characteristics that affect the choice of alternative climate-smart practices, then Eq. (3) becomes an MVP model. Studies have employed Geweke–Hajivassiliou–Keane (GHK) to compute the maximum likelihood function based on a multivariate normal probability distribution [29]. The GHK simulator is primarily based on a multivariate normal distribution function that can be expressed as the product of sequentially conditioned univariate normal distribution functions, which can be accurately evaluated [30]. The current study, therefore, will use the GHK simulator to estimate the equations using the maximum likelihood method. The implicit functional form of the empirical model will be specified as follows:

$$Y_n^{*} = fx(\beta_0 + \beta_1 Age + \beta_2 Gender + \beta_3 Educ + \beta_4 active + \beta_5 active + \beta_{65} farmsize + \beta_7 distmkt + \beta_8 Extent + \beta_9 credit + \beta_{10} Offarm + \beta_{11} Cropdiversfy + \ \ + \beta_{12} Indigeknwldge + + \beta_{13} Soilfertily + + \beta_{10} Grpmembshp) + \varepsilon \qquad (4)$$

The variables and measurements of the variables that will be modelled are shown in Table 2 below.

Table 2. Measurement of Variables.

Variable	Description of the variable	Measurement	Sign
Dependent variable Y_I	Climate-smart practices agroforestry, planting drought tolerant crops, use irrigation, organic fertilizer and use of green manure	0= Not adopted 1=adopted	+
Independent variable Gender	Gender of household head	Dummy; 1=Male and 2=Female	+/-
Age	Age of household head in years	Age in years	+
Shooling years	Maximum years of schooling attained by the household head	Continuous; Maximum Years spent in school	+
activemebers	Number of active household members age between 15 to 64 years	continuous	+
inactivemebers	Number of active household members aged less than 15 to above 64 years	continuous	-
Offarm	Received off-farm income	Dummy; 1=Yes and 0=No	+/-
Farmsize	Farm size in acres	Continuous	+/-
soilfertility	Soil fertility status	Dummy; 1=fertile and 0=infertile	
Extension	Access to extension services	Dummy; 1=Yes and 0=No	+
Mktdistance	Distance to the nearest market in Kilometers	Continuous	+/=
Creditaccess	Receive credit	Dummy; 1=Yes and 0=No	+
groupmember	Group membership to farmer-based organizations	Dummy; 1=Yes and 0=No	+/-
cropdivesification	Planting numerous crops	Dummy; 1=Yes and 0=No	+
Useindegkwledge	Use of indigenous knowledge in farm decision making	Dummy; 1=Yes and 0=No	+/-

4. Descriptive Characteristics of Sampled Households

4.1 Descriptive Statistics

Summary statistics for the continuous household characteristics and farm characteristics were presented in Table 3. The descriptive statistics show that household heads had an average 9 years of schooling (SD=5.95) and mean age of 44 years (SD=14.26), illustrating differences in education attainment and age across sampled smallholder farmers households. The average household consists of 7 members of which about 4 are classified as active members and 3 as inactive members. The average dependency ratio was 0.78, showing on average approximately 78 dependents per 100 active household members.

Concerning land resource ownership, on average households owned 7.85 acres but cultivated approximately 2.72 acres. The vast majority between average land size owned and cultivated area shows that not all land owned was under cultivation during the reference period. The absolute large standard deviation of land owned (10.56 acres) compared with the mean suggest considerable differences in landholding sizes.

Access to institution support services was reported to vary amongst the sampled farm households. On average households were located 8.32 km from the nearest extension service provider office and 4.77 km from the nearest market. These distances may be important on adoption decision since access to extension services and market influences information access, input availability and marketing of agricultural produce.

Table 3. Descriptive statistics of continuous explanatory variables.

Variable	Mean	Std. dev.
Schooling years of household head	9.05	5.95

Variable	Mean	Std. dev.
Age of the household head	44.01	14.26
Household size	7.43	4.37
Active members	4.34	2.51
Inactive members	3.09	2.56
Dependency ratio	0.78	0.65
Land owned acres	7.85	10.56
Log land owned	1.80	0.81
Farmed size acres	2.72	3.23
Log farm size	1.08	0.64
Distance to Extension agent office (Km)	8.32	6.30
Distance to nearest Market (Km)	4.77	5.19

The sampled household were characterized by considerable differences in education, age, household composition, land ownership and access to institutional support services. These characteristics were important in understanding farmers' ability to access information, mobilize farm labor, invest in agricultural technologies and respond to climate-related production shocks. The average years of schooling suggest that the respondents' had attained, primary education, but larger standard deviation shows variations in years of schooling. Education is useful to facilitate farmers' ability to understand technical information, evaluate the expected benefits of agricultural innovation and access extension services [3]. The average household head of 44 years shows that sampled farmers were from different stages of working. Age influences adoption through accumulation of farm experience, risk attitude, access to farm production resources and willingness to try unfamiliar practices. Experienced farmers have more knowledge of local climatic conditions, while younger farmer may be more willing to experiment with new agricultural technologies [8].

Household composition may have implied that agricultural labor availability and resource allocation. A larger household size may provide labor for practices such as agroforestry development, organic fertilizer application and irrigation management. A higher dependency ration increase burden that raises consumption requirements and constrains financial resources available for agricultural investment. Competition means household size and dependency ratio differences effects on adoption climate-smart practices. The importance of household composition agreed to previous studies found that household size relate with awareness and adoption of climate-resilient practices [13]. Land ownership and cultivated area show variations, suggesting that average area cultivated was lower than the average area owned. The substantial dispersion in landholding sizes shows heterogeneity in land resources availability which may affect adoption differently across practices; agroforestry requires more land for establishing trees, while irrigation dependents on suitable access to land and water. Drought-tolerant crop varieties, organic fertilizer and green manure use, may be feasible on small plots, but adoption depends on input availability, labor and farmers' objective. Access to extension and market suggests that variations across sampled households. Distance to the nearest extension agent office influences farmers' opportunities to acquire technical advice on drought-tolerant varieties, agroforestry management, irrigation, and use of green and organic manure. Similarly, distance to the nearest market influences the cost of acquiring inputs and access output market [9, 13].

Distribution of selected categorical household and farm characteristics amongst sampled smallholder farmers were presented in Table 4. The results demonstrate gender-disparities, variations in income sources, access to agricultural institutional support services, perceived soil fertility, membership for farmer-based organizations and access to credit. These characteristics provide important context for evaluating the institutional and resource conditions under which farmers make decisions about adoption of agricultural practices.

Gender of the household head reported that majority were male-headed households (53.6%) while fewer were female-headed (46.4%). Gender influenced adoption of climate-smart practices through variations in accessing production resources, finance, labor land ownership, agricultural information and decision-making authority. Approximately 65.6% of the respondents received off-farm income, illustrating that non-farm activities were an income source for a significant proportion of the sampled households. Access to off-farm income lower liquidity constraints and allows households to acquire inputs such as seeds, organic fertilizers, irrigation equipment. Also, access to off-farm activities lowers adoption through competition with farming time and household labor force.

Fewer of the sampled households have access to climate-smart support services (9.7%). The lower proportion indicates that specialization support might not have a broader accessibility to the sampled households. Limited to relevant information, training, and technical assistance limits farmers' ability to assess and utilize agricultural practices.

Table 4. Summary statistics of categorical farm and household characteristics.

Variables	Category	Frequency	Percent (%)
Gender of the household head	Male	209	53.6
	Female	181	46.4
Received off-farm income	Yes	256	65.6
Access to climate-smart support services	Yes	38	9.7
Plots fertile status	Yes	302	77.4
Received extension services	Yes	35	9
Membership farm group	Yes	85	21.8
Receive credit	Yes	175	44.9

Majority of the farmers (77.4%) reported their plots were very fertile, suggesting that farmers' perception of soil fertility rather than actual measurement of soil fertility. Perceived soil fertility influenced farmers' decisions on adoption of soil fertility management, green manure use, organic fertilizer application, crop selection and investment on land enhancement practices. Results displayed low access to extension services with approximately 9% having access to extension services, suggesting limited coverage of extension officers amongst sampled households. Extension services access provides information on management, costs and projected benefits of adoption of modern agricultural practices. Farmer-based organization members were found to be lower with only 21.8% of the farmers sampled were in farmer groups. Group promotes exchange of agricultural knowledge, collective access to inputs, training opportunities, and linkages to market or support services. Majority of the sampled households (55.1%) did not have access to credit. Credit is relevant in relaxing financial constraints link to inputs purchase, creating agroforestry systems, and investing in irrigation infrastructures which depends on loan availability, affordability, repayment conditions and suitability of credit to the investment requirements of practice to be adopted.

4.2. Adoption Patterns of Climate-smart Practices

Table 5 presents the adoption pattern of climate-smart practices in West Pokot County. The adoption of climate-smart practices differs across the survey sampled smallholder farmers in West Pokot County. Agroforestry reported the highest adoption rate (48.21%), followed by planting of drought-tolerant crop varieties (46.15%), green manure (23.59%), organic fertilizer (20.26%) and use of irrigation (10.26%). These results show that majority of smallholder farmers in West Pokot County recorded higher utilization of tree-based and crop-variety strategies than use of irrigation and soil fertility management practices. This trend is consistent with previous research conducted in Kenya that reported that smallholder farmers apply a range of climate-smart agricultural practices, while adoption varies across technologies and amongst farmers households [9, 13].

Table 5. Distribution of adoption of climate-smart practices in West Pokot County.

Climate-smart Practice	Adopters (%)	Non-Adopter (%)
Agroforestry	48.21	51.79
Drought-tolerant crop varieties	46.15	53.85
Use of irrigation	10.26	89.74
Use of organic fertilizer	20.26	79.74

Climate-smart Practice	Adopters (%)	Non-Adopter (%)
Use of green manure	23.59	76.41

Agroforestry was adopted by 48.21% of the sampled households, making it the most widely adopted practice in West Pokot County. Results were aligned to West Pokot's drylands farming system that integrates trees with crops and livestock farming for supporting soil conservation, provides fodder and fruits for enhancing reclamation of degraded lands. A study conducted in West Pokot reveals the importance of agroforestry and reforestation as a strategy for enhancing food security and adaptive capacity for climate shocks [25]. Drought-tolerant crop varieties were adopted by 46.15% of the sampled smallholder farmers. This recorded relatively high adoption rate implying that almost half of the sampled smallholder farmers were using crop varieties identified for their ability to perform under moisture stress. Such varieties enable farmers manage rainfall variability and lower risk of crop failure, but their yield depends on seed quality, suitability to local conditions and crop management practices applied by the farmer. Previous research conducted in Kenya identified the use of drought-tolerant and early maturing crop varieties as an adaptation alternative for climate and livelihood shocks [31, 32].

Use of irrigation documented the least adoption rate of 10.26%, with the majority 89.74% reported not using irrigation amongst sampled farmers in West Pokot County. These results revealed that irrigation was less commonly applied compared to other climate-smart practices. In semi-arid settings such as West Pokot County, irrigation lowers high dependency on rain-fed agriculture and supports crop production even during periods of droughts. Similar findings were reported in Makueni County where irrigation record lowest adoption rate of 1.56% [22]. Low adoption rate is attributed to low access to credit, farm assets, poor access to water and extension services.

Organic fertilizer application was 20.26% of the sampled farmers, with 79.74% never applied organic fertilizer in their farms. This implies organic fertilizer was not widely adopted by majority of farmers, despite its significant contribution to soil fertility management. Organic inputs such as animal manure and compost contribute to nutrient recycling and enhance soil organic matter, but their effectiveness relied on quality, quantity, availability, and correction application of the material. The absolute low adoption of organic manure in West Pokot justifies investigation to whether farmers in West Pokot have adequate livestock manure, access to composting training, labor and extension services. Adoption of green manure recorded lower rates with only 23.59% applied green manure in their farms, compared to 76.41% who did not apply green manure. Green manure involves the use of growing plants; legumes cover crops to incorporate biomass into the soil for improving soil organic matter and nutrient recycling. Adoption rate of green manure is influenced by land availability, rainfall patterns, access to seed, labor availability, and whether a farmer has enough land to allocate for cover crops harvested not for sale or food but for soil fertility management.

4.3. Determinants of Adoption of Selected Climate-smart Practices: Multivariate Probit Results

Table 6 presents variance inflation factor (VIF) findings applied to determining potential multicollinearity amongst continuous explanatory variables used in the study. Multicollinearity occurs when two or more explanatory variables are strongly correlated, resulting in inflating standard errors and making it difficult to differentiate individual interconnections with the outcome. The results showed that the VIF values range from 1.03 to 1.41, with a mean VIF of 1.18. From Table 6 all values are substantially below the threshold of 5 or 10, implying the selected explanatory variables do not exhibit a serious level of multicollinearity [33]. Therefore, multicollinearity was not a major concern amongst the explanatory variables selected.

Table 6. *Variance inflation Factors (VIF).*

Variable	VIF	1/VIF
Active member	1.41	0.71
Inactive members	1.33	0.75
Age of HH	1.17	0.86
Schooling years of HH	1.1	0.91
Distance to Market Km	1.04	0.96
Log Farm acres	1.03	0.97
Mean VIF	1.18	

Table 7 presents results for the contingency coefficient amongst categorical explanatory variables. Among the categorical variables, no pairwise correlation exceeded 0.5. This shows multicollinearity was not a problem amongst the categorical variables in the model [33, 34]. Therefore, values below 0.5 indicate that the categorical variables are suitable for use in the MVP regression estimates.

Table 7. *Contingency coefficient test.*

Variables	gender	Received off-farm	Crop diversification	Apply indigenous knowledge	Received extension	Group membership	Access credit	Plot fertility
Gender of HH	1							
Received off-farm	0.1428	1						
Crop diversification	-0.0735	-0.0037	1					
Apply indigenous knowledge	0.0173	0.0249	-0.1734	1				
Received extension	-0.0404	0.0383	0.103	-0.1169	1			
Group membership	-0.1052	0.0419	0.1099	-0.071	0.2036	1		
Access credit	-0.0126	0.0231	0.0901	0.0589	0.1316	0.4228	1	
Plot fertility	-0.0841	-0.0099	-0.3912	0.2754	-0.1051	-0.0027	0.179	1

Heteroscedasticity test was conducted using Breusch-Pagan and white test in Table 8. The Breusch-Pagan test results of $\{x^2(6.97), p = 0.0083\}$ indicated the presence of heteroscedasticity. Results were reaffirmed by white test $\{x^2(143.23), df = 111, p = 0.020\}$ indicating the presence of heteroscedasticity (Table 8). The study recommended the use of robust standard errors to eliminate the presence of heteroskedasticity while executing MVP regression model.

Table 8. *Cameron & Trivedi's decomposition of IM-test.*

Source	chi2	Df	p-value
Heteroskedasticity	143.23	111.00	0.02
Skewness	75.39	14.00	0.00
Kurtosis	52.39	1.00	0.00
Total	271.01	126.00	0.00

Pairwise correlation amongst the five climate-smart practices results were presented in Table 9. Results have been exposed that heterogenous interconnection between adoption decisions, implying some practices may be adopted together, while others may reflect different household priorities. The existence of significant relationships between selected adoption indicators motivates further examination of whether adoption decisions shared unobserved determinants. Thus, multivariate probit model was appropriate for joint evaluation of the determinants of adoption of the five climate-smart practices, while allowing the error terms across the five equations to be correlated [8, 35].

Table 9. *Correlation between climate-smart practices adopted by farmers.*

Practices	Agroforestry	Drought tolerant	Use irrigation	Use organic Fertilizer	Use green manure
Agroforestry (0=no 1=yes)	1				

Practices	Agroforestry	Drought tolerant	Use irrigation	Use organic Fertilizer	Use green manure
Drought tolerant (0=no 1=yes)	-0.1932***	1			
Use irrigation (0=no 1=yes)	0.0121	0.0261	1		
Use organic Fertilizer (0=no 1=yes)	0.2671***	0.1349***	0.0609	1	
Use green manure (0=no 1=yes)	0.1167	0.1761***	0.0311	0.0956*	1

The goodness of fit of multivariate probit model was tested using log likelihood, Wald chi-square test and Log pseudo likelihood values. Loglikelihood ratio test shows the unrestricted MVP model and correlation of the error terms. Likelihood ratio test Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0 reject the test of multiple adoption of different climate-smart practices was rejected, showing multiple adoption of various climate-smart practices were not mutually exclusive and MVP model fit the data well. Wald chi-square test of $\{x^2(10) = 40.109, p < 0.001\}$ and Log pseudolikelihood value of -882.2568 indicates joint significance of the error term confirming the appropriateness of the application of MVP model estimate the determinants of adoption of climate-smart practices in West Pokot County (Table 10).

Table 10. *Marginal effects estimations of drivers of implementation of climate-smart practices in West Pokot County.*

	Agroforestry	Drought tolerant	Use Irrigation	Use of organic fertilizer	Use of green manure
	dy/dx	dy/dx	dy/dx	dy/dx	dy/dx
Gender of HH (1=male 2=female)	-0.0575 (0.0222)	-0.0635 (0.0245)	-0.0084 (0.0032)	-0.1097** (0.0423)	-0.0185 (0.0071)
Age of HH	0.0026* (0.0010)	-0.0003 (0.0001)	0.0029 (0.0011)	0.0040** (0.0015)	0.0030* (0.0011)
Schooling Years of HH	0.0060 (0.0023)	-0.0052 (0.0020)	0.0016 (0.0006)	0.0011 (0.0004)	0.0001 (0.0000)
Received Off-farm (0=no 1=yes)	-0.0768 (0.0296)	-0.0164 (0.0063)	-0.0237 (0.0091)	-0.1018** (0.0393)	-0.0086 (0.0033)
Active members	0.0005 (0.0002)	0.0004 (0.0002)	0.0081 (0.0031)	-0.0068 (0.0026)	-0.0086 (0.0033)
Inactive members	-0.0036 (0.0014)	-0.0072 (0.0028)	-0.0008 (0.0003)	-0.0070 (0.0027)	-0.0039 (0.0015)
Crop diversification (0=no 1=yes)	0.4333*** (0.1671)	0.1288* (0.0497)	-0.2355*** (0.0908)	0.3270*** (0.1262)	0.2369*** (0.0914)
Apply indigenous knowledge (0=no 1=yes)	-0.3271*** (0.1262)	0.0825* (0.0318)	-0.1208 (0.0466)	0.0241 (0.0093)	-0.1246** (0.0481)
Log Farm acres	0.0681* (0.0263)	0.0333 (0.0129)	-0.1281** (0.0494)	0.0848** (0.0327)	0.0078 (0.0030)
Received Extension (0=no 1=yes)	0.0032 (0.0012)	0.0798 (0.0308)	0.2432*** (0.0938)	0.0061 (0.0024)	-0.0161 (0.0062)
Distance to Market Km	-0.0045 (0.0018)	0.0022 (0.0008)	-0.0164** (0.0063)	-0.0065 (0.0025)	-0.0008 (0.0003)

	Agroforestry	Drought tolerant	Use Irrigation	Use of organic fertilizer	Use of green manure
	dy/dx	dy/dx	dy/dx	dy/dx	dy/dx
Group membership (0=no 1=yes)	0.0764 (0.0295)	-0.0489 (0.0189)	-0.1055 (0.0407)	0.1620*** (0.0625)	-0.0100 (0.0039)
Access credit (0=no 1=yes)	-0.0968* (0.0373)	0.0575 (0.0222)	0.0185 (0.0071)	-0.1194** (0.0461)	0.0779 (0.0301)
Plot fertility (1=fertile 2=not fertile)	-0.1658*** (0.0640)	0.3980*** (0.1535)	-0.1907** (0.0736)	0.0002 (0.0001)	0.2073*** (0.0800)
Constant	-0.1908 (0.0736)	-0.5202*** (0.2007)	0.1062 (0.0410)	-0.5188** (0.2001)	-0.7363*** (0.2840)
Log pseudolikelihood = -882.2568, Wald chi2 (70) = 325.91, Prob > chi2 = 0.0000					
Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0: chi2 (10) = 40.109 Prob > chi2 = 0.0000					

Notes: *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$. Robust standard errors are reported in parentheses. Reported estimates are Average Marginal Effects (AMEs).

The marginal effects of determinants of adoption of climate-smart practices were presented in Table 10. *Agroforestry:* Approximately 48.21% of the sampled households were using agroforestry as an climate-smart practice on their farms. Age of the household head($\beta = 0.0026, \mathrm{p} < 0.10$), crop diversification ($AME = 0.4333, \mathrm{P} < 0.01$), and farm size acreage ($AME = 0.0681, \mathrm{P} < 0.10$), were positively associated with adoption of agroforestry, while application of traditional knowledge ($AME = -0.3271, \mathrm{P} < 0.01$), access to credit($AME = -0.0968, \mathrm{P} < 0.10$), and plot with less fertility ($AME = -0.1658, \mathrm{P} < 0.01$), had a negative associated with trees planting in the farm. *Planting drought tolerant crop varieties:* About 46.15% were planting drought tolerant crop varieties in their farms. Crop diversification ($AME = 0.1288, \mathrm{P} < 0.10$), use of indigenous knowledge ($AME = 0.0825, \mathrm{P} < 0.10$), and fertile plot ($AME = 0.3980, \mathrm{P} < 0.01$) positively correlates with planting of drought tolerant crop varieties (Table 10).

Use of irrigation: Lower number of smallholder farmers, approximately 10.26% adopted irrigation in their farms for crop production. Access to extension services ($AME = 0.2432, \mathrm{P} < 0.01$) positively associated with uptake of irrigation for crop production, while crop diversification($AME = -0.2355, \mathrm{p} < 0.01$), farm size($AME = -0.1281, \mathrm{P} < 0.05$), distance to the nearby market($AME = -0.0164, \mathrm{P} < 0.05$), and infertile plots ($AME = -0.1907, \mathrm{P} < 0.05$), negatively influences adoption of irrigation. *Use of organic fertilizer:* Approximately 20.26% were using organic fertilizer in crop production in West Pokot County. Age of the household head ($AME = 0.0040, \mathrm{P} < 0.05$), crop diversification ($AME = 0.3270, \mathrm{p} < 0.01$), farm size acres ($AME = 0.0848, \mathrm{P} < 0.05$), and group membership ($AME = 0.1620, \mathrm{P} < 0.01$) positively associated with use of organic fertilizer, while gender of the household head ($AME = -0.1097, \mathrm{P} < 0.05$), participation in off-farm income activities ($AME = -0.1018, \mathrm{P} < 0.05$), and access to credit ($AME = -0.1194, \mathrm{P} < 0.05$), negatively associated with use of organic fertilizer. *Use of green Manure:* Approximately 23.59% were applying green manure in their farms for enhancing crop production. Age of the household head ($AME = 0.0030, \mathrm{P} < 0.10$), crop diversification ($AME = 0.2369, \mathrm{P} < 0.01$), and fertile plot ($AME = 0.2073, \mathrm{P} < 0.01$), positively influence the use of green manure. While application of indigenous knowledge ($AME = -0.1246, \mathrm{P} < 0.05$), negatively influence adoption of green manure (Table 10).

4.4. Discussions

The gender of the household head was statistically significant and negatively related to the application of organic manure among smallholder farmers in West Pokot County (Table 10). Results indicates that female-headed households were less inclined to adopt organic fertilizers compared to male-headed households, with a 10.97% lower likelihood of adoption. A plausible explanation for gender-disparity may indicate that women's had limited access to agricultural productive resources, such as extension services, cultural norms, land ownership, financial resources, and agricultural information, which limit adoption of organic fertilizer [36-39]. Since organic fertilizer application is labor-intensive practices, entails the collection and transportation of animal manure, compost preparation, field application, and transport to the plots, female-headed households may have limited labor and resources to apply organic manure effectively [40-42]. The results were in tandem with previous studies which reported

male-headed household were more likely to adopt organic-based soil fertility management technologies such as animal than female-headed households [40, 43] The gender difference in application of organic fertilizer was related to unequal access to resources and agricultural resources, labor availability.

The age of the household head was statistically significant and had a positive influence on utilization of organic and green manure in West Pokot County. Older farmers were more inclined to adopt soil fertility management practices compared to younger farmers, and extra year of the household head increased the adoption of organic manure by 0.4% and green manure by 0.3% (Table 10). The possible reason may be because older farmers have extensive farming experience and traditional knowledge, build over long periods on how to effectively apply agricultural practices which are beneficial. Accumulated knowledge promotes adoption of long-term farm practices such as application of organic fertilizer and green manure, which improves soil structure, moisture content, boost microbial activity, and support sustainable crop productivity [44]. In addition, elderly farmers have access to production resources and own more livestock compared to younger farmers, which produces adequate manure for promoting application of organic nutrients on their farms. These findings support previous research conducted that reported a significant positive association between the age of the household head and the adoption of farmyard manure because of greater awareness of soil fertility decline and knowledge of sustainable land management practices [13, 40, 45].

Farm households that received off-farm income activities were statistically significant and had a negative association with adoption of organic fertilizer in West Pokot County. Farm households receiving off-farm income activities were less inclined to apply organic fertilizer compared to their counterparts without off-farm income activities. A plausible reason may be because off-farm income activities compete with labor and time allocated for farming activities for labor-intensive agricultural technologies, such as applying organic fertilizer, preparing compost, collecting animal manure, and transporting it to the fields, limiting labor and time for utilization of the practices. Organic manure application requires more labor and frequent management, which can be difficult for households that spend most of their time in off-farm employment [43, 45, 46]. Such households may prefer less intensive agricultural practices and avoid investing in soil fertility management practices. Results agreed with previous findings that documented a negative relationship between organic fertilizer adoption and access to off-farm income [40, 47-49].

Practicing crop diversification was positively and statistically significant with adoption of agroforestry, drought-resistant crop varieties, organic fertilizer, and green manure, while negatively and statistically significantly associated with adoption of irrigation in West Pokot County. Positive association implies that households that plant a highly diverse set of crops are more inclined to apply multiple climate-smart practices compared to farmers planting fewer crops. Crop diversification acts as climate variability adaptation management strategy that encourages integration of complementary sustainable agricultural practices for enhancing soil fertility, promote crop production, conserve the biodiversity, and strengthen household livelihood and resilience [3, 40, 50-52]. Besides, crop diversity enhances synergies among trees, crops, and organic soil nutrients, improving soil nutrient cycling, pest control, soil organic matter, and efficient resource application [41, 54]. Farmers engaging in crop diversification are more inclined to invest in organic manure, drought-tolerant crop varieties, and agroforestry as complementary techniques rather than as a single practice [22, 40, 53, 54].

Application of indigenous knowledge by smallholder farmers had negative and statistically significant association with the adoption of agroforestry and green manure, but positively and statistically significant correlation with planting of drought-tolerant crop varieties in West Pokot County. Dependence on traditional knowledge constrains the adoption of green manure and agroforestry in West Pokot County, this suggests dependence on traditional, hereditary agricultural methods constrains the integrating modern agroecological practices. Farmers who depend absolutely on indigenous knowledge may adopt climate-smart practices, such as the use of green manure, as inconsistent with traditional farming systems [32]. Traditional knowledge systems are usually location-specific and often reluctant to adopt new scientific recommendations on nutrient recycling and integrated soil fertility management, resulting in low adoption rates of modern climate-smart practices [55-57]. Moreover, indigenous knowledge encourages the adoption of drought-tolerant crop varieties in West Pokot County. Farmers who depend on indigenous knowledge are more inclined to plant drought-tolerant crop varieties compared to those not utilizing indigenous knowledge. This may be because indigenous knowledge enables farmers to master environmental changes such as temperature, rainfall patterns, soil moisture content, and seasonal weather changes, and thus gives guidance on the choice and conservation of crop varieties that endure droughts [58, 59]. Indigenous knowledge also enhances the conservation and exchange of locally produced seeds that can survive in harsh environmental conditions [60]. This finding is in line with previous research which concluded that indigenous knowledge plays an important function in the preservation and sustained use of drought-tolerant traditional crops, as local understanding permits farmers to determine resilient crop species that are adaptive to vulnerable environments such as limited rainfall and harsh weather conditions.

Farmed acres had positive and statistically significant influence on adoption of agroforestry and the utilization of organic fertilizer, while negatively and statistically associated with the use of irrigation in West Pokot County. Farmers owning larger farm sizes were more likely to integrate trees into their farming systems and use organic fertilizer than farmers owning

smaller farm sizes. The possible explanation may be farmers owning larger farm sizes offer adequate space to grow trees without reducing land allocated for crop production, allowing farmers to experiment with long-term land management techniques such as agroforestry while facing fewer land-use trade-offs compared to farmers with smaller farm sizes [45]. In addition, larger farm sizes also produce more crop residues and usually support more livestock, thereby generating enough manure and organic waste to produce organic manure [22]. Farmers owning large plots were able to finance sustainable soil fertility management because of stronger incentives to maintain soil productivity over the long term [46]. Results were consistent with previous studies that concluded that larger farm size promotes adoption of multiple soil fertility management practices, including manure application and sustainable agroforestry [8, 61].

Farmed size had negative and statistically significant association with the use of irrigation in West Pokot County. Farmers with larger landholdings were less inclined to adopt irrigation compared to farmers with smaller landholdings. Irrigation infrastructure requires huge financial resources, adequate water supply, high operation and maintenance costs, which are burdensome for larger landholdings [62]. On a large farm, irrigation increases the cost of water supply, pipes, pumps, labor, and storage facilities. Thus, farmers with larger farm sizes produce selectively during rainy seasons, as irrigating the entire large farm is economically very expensive [63]. Farmers with small pieces of land may invest in irrigation as it is affordable and manageable. Small farms use irrigation for highly valued horticultural crops, which are profitable under irrigation, but allocate the rest of the farm to extensive rainfed cereals and livestock production, reducing the incentive to invest in irrigation practices [64]. Similar findings were reported in previous studies that concluded negative association between farm size and application of irrigation [65].

Access to extension services had positive and statistically significant influence on the application of irrigation in West Pokot County. This implies that farm households who received agricultural extension services were more inclined to use irrigation compared to those who did not receive extension services. A plausible reason is that extension services enhance farmers' knowledge and technical skills related to irrigation planning, water-use efficiency, crop water requirements, maintenance of irrigation facilities, and irrigation system management [63]. Extension agents serve as a channel for the dissemination of climate information on new agricultural technologies, training farmers, running demonstration plots for irrigation, facilitating credit access, and facilitating government irrigation schemes [22, 66]. Farmers receiving additional extension visits are more likely to receive knowledge on the environmental and economic benefits of irrigation and use the technology. Similar results were documented in previously found a positive association between access to extension services and the adoption of climate-smart technologies [62, 67].

Distance to the nearest market reported negative and statistically significant association with adoption of irrigation in West Pokot County. This implies that farmers furthest from the market were less likely to adopt irrigation than those closer to market. A possible explanation is that proximity to market centers lowers transportation costs and enhances access to irrigation equipment, extension services, agricultural inputs, repair of agricultural equipment, and market information [64]. Farmers located near the market were in a better position to produce highly valued, perishable crops, such as vegetables, fruits, and horticultural crops, as the market is easily accessible at competitive prices, thus increasing profits and improving investment in irrigation. However, farmers located far from the market incurred high transportation costs, had limited access to extension services, had reduced market opportunities, and faced poor road access to the market, discouraging investment in irrigation infrastructure [63]. Results agreed with previous research that deduced that distance to the market negatively influenced adoption of irrigation [62, 64, 65, 68].

Membership in a farmer-based organization reported positive and statistically significant association with the use of organic fertilizer in West Pokot County. This suggests that households belonging to farmer-based organization groups were more likely to adopt organic fertilizer than those without groups. A possible explanation is that farmer groups offer important platforms for sharing information, knowledge, experience, and sustainable agricultural practices. Group meetings, demonstration plots, and peer-to-peer learning enable farmers to acquire practical skills in compost production, manure management, and integrated soil fertility management [40]. Farmer groups enhance access to agricultural training, extension services, and credit, and facilitate collective action in acquiring agricultural inputs, lowering transaction costs and information search, and boosting the use of organic fertilizer [69]. Results were supported by previous research that reported a positive association between farmer groups and adoption of integrated soil management practices [46, 70, 71].

Access to credit negatively correlated with adoption of agroforestry and the use of organic fertilizer in West Pokot. This implies that households who received credit were more likely to uptake agroforestry and organic fertilizers than those who did not receive credit. The negative coefficient of credit could be explained by diverted use of credit received to competing households' needs and short-term agricultural activities rather than long-term climate-smart practices such as agroforestry [56]. Majority farmers normally seek credit to meet immediate agricultural production costs, such as purchasing inputs like inorganic fertilizers and hybrid seeds, and household consumption requirements, leaving them with little for long-term agricultural investments, such as planting trees and enhancing soil fertility through organic inputs [72, 73]. Agroforestry and organic fertilizer utilization are limited by the short-term repayment period of loans in rural areas, discouraging investments in delayed benefits such as agroforestry, as trees require

many years to mature to earn economic returns, thus discouraging farmers from investing borrowed funds to establish trees to repay pressure [50, 70, 72]. Organic fertilizer requires more labor and is a consistent practice that requires larger capital and complementary services such as extension, knowledge and labor to translate its benefits.

Perceived plot fertility reported negative and statistically significant influence on adoption of agroforestry and the use of irrigation in West Pokot. The negative coefficient implies that farmers perceiving their plots are infertile were more likely to use agroforestry and irrigation than those who perceived their plots fertile. A plausible reason is that farmers who perceived their plots to be infertile were more willing to invest in land restoration and productivity-improvement practices. Agroforestry is useful for enhancing soil organic matter, improving nutrient cycling, conserving moisture, and controlling soil erosion; therefore, these strategies are most preferred by farmers experiencing soil degradation [46, 74]. Irrigation can offset low soil productivity by enhancing access to water, helping farmers in increasing crop production and reducing the effects of unpredictable rainfall [8]. Farmers with fertile plots were less willing to invest in agroforestry and irrigation, as their existing production may be sufficient under rain-fed conditions. Thus, the observed marginal benefits of using supplementary agricultural technology may decline amongst households with fertile soil [40].

However, soil fertility reported positive and statistically significant effect on the adoption of drought-tolerant crop varieties and the use of green manure in West Pokot County. This suggested that farmers who perceived their plots to be fertile were more likely to use drought-tolerant crop varieties and integrate green manure practices into their farming methods. Farmers perceiving their plots to be very fertile were having high level of awareness and ability and are motivated to invest in practices that sustain crop productivity and improve household resilience to climate shocks [69, 75]. The positive association between drought-tolerant crop species and soil fertility is attributed to farmers' use of multiple genetic materials that promote soil conditions. Drought-tolerant varieties are cultivated to withstand low moisture and perform best when soil nutrients are available [40, 46]. Farmers with fertile soil invest in improved seed varieties to enhance higher productivity. Farmers with very fertile soil have access to agricultural advisory services, information on production, and enhanced seed systems that increase adoption of climate-resilient crop varieties [13].

5. Conclusions and Recommendations

5.1. Conclusions

The findings revealed that there is heterogeneous adoption patterns across climate-smart practices in West Pokot County with agroforestry recorded highest adoption rate (48.21%, followed by drought-tolerant crop varieties (46.15%). Soil fertility management practices recorded lower adoption rates with green manure (23.59%) and organic fertilizer (20.26%). Irrigation was the least adopted practice (10.26%) in West Pokot County. Results of multivariate probit model indicate that crop diversification is the most significant determinant positively associated with adoption of agroforestry, drought-tolerant crop varieties, organic fertilizer and green manure, but negatively associated with irrigation, demonstrating practice-specific nature of farmers' household decision making. While household head age, farm size, membership to farmer group, access to extension services perceived plot soil fertility, use of indigenous knowledge, off-farm income and access to credit exhibiting different relation with adoption of climate-smart practices. Extension access was significantly influencing use of irrigation, and farm group membership promotes use of organic fertilizer. Credit access negatively influences adoption of agroforestry and organic fertilizer use, implying that access to financial resources alone does not promote investment in sustainable agricultural practices. Generally, adoption of climate-smart practices is mainly influenced by interaction of household characteristics, farm-level resources, access to institutional support services and farmers knowledge and perception about soil fertility. Therefore, promoting climate-smart practices in West Pokot County requires various interventions that address the different constraints and allowing conditions related with practices rather than depending on uniform methods to agricultural technology promotion.

5.2. Recommendations

County and national government, agricultural extension agencies, policy makers and development partners to implement integrated but practice-specific climate-smart strategies that strengthen farmers' ability to adopt complementary resilient agricultural practices. Extension services should be extended thought farmer field schools, demonstration plots and locally adapted training on agroforestry, drought-tolerant crop varieties, organic fertilizer, green manure and water efficient irrigation system, with most attention to the low adopted irrigation. Farmer based organizations to be strengthen as a platform for collective learning, access of inputs, peer-to-peer knowledge exchange and soil fertility management, while extension provider to work with pastoral and agro pastoral communities to integrate locally important indigenous knowledge for improving agricultural technologies rather than displacing existing agricultural practices. Agricultural financial programs should give affordable credit with repayment schedule aligned with seasonal farm cash flows and the longer maturity periods of agroforestry investment, complemented by grants or cost-sharing arrangement is possible. County agricultural programs to enhance crop diversification and integrated soil fertility management while considering irrigation decisions may require targeted interventions addressing water availabil-

ity, infrastructure costs, farm-level feasibility and market access. Agricultural interventions should be targeted to various farm size, soil conditions, gender, and livelihoods activities, including measure that lower labor and resources constraints to vulnerable households. The county government should evaluate adoption rates, sustainability uses and outcomes such as soil health, crop productivity and household resilience to determine the best combination of agricultural practices which offers maximum benefits in West Pokot diverse agroecological conditions.

Abbreviations

VIF	Variance Inflation Factors
MVP	Multivariate Probit
SD	Standard Deviation
GHK	Geweke–Hajivassiliou–Keane
ODK	Open Data Kit
KNBS	Kenya National Bureau of Statistics
STATA	Statistics and Data

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Author Contributions

Beryl Atieno Ouma: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Resources, Software, Writing – original draft, Writing – review & editing

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Data Availability Statement

Data used for this study will be readily available upon formal request

Conflicts of Interest

The authors declare no conflict of interest.

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