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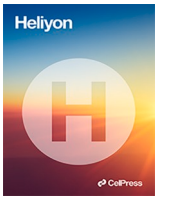

Networking and training for IMPROVEMENT of farm income: A case of lifelong learning (L3F) approach in West Africa

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ABSTRACT

The lifelong learning for farmers program of the Commonwealth of Learning relies heavily on innovation platforms to address the critical information gap left by agricultural research and development, which often fails to reach the intended rural farmers. The fundamental tenet is that these activities require a space for stakeholders to collaborate, overcome obstacles, and seize opportunities for agricultural development. Therefore, this study investigated the impact of networking and training on farm income in West Africa. A multistage sampling technique was employed to select 1800 households from the study site which cuts through the Kano-Katsina axis in Nigeria and the Maradi axis in the Niger Republic. The probit and mediation models were used to analyse the data. The probit model suggested that the decision to join innovation platforms is significantly influenced by factors such as married status, education, household size, farming experience, and the proportion of males and females in the working class, and young dependents. Furthermore, the probit model shows that the decision of farmers to take part in the training offered by innovation platforms is significantly influenced by factors such as gender, age, years of education, household size, and the proportion of males and females in the working class as well as elderly dependents. The mediation analysis results showed a positive and significant correlation between farm income and membership in innovation platforms (IPs). The direct effect suggested that farm incomes rise by 77.5 % upon joining IPs. Upon breaking down the overall impact into direct and indirect effects, it became evident that participation in IP training mediated nearly 86 % of the total impact of IP membership on farm income. The study concludes that participation in innovation platforms has a positive effect on farm income when they take part in educational programs hosted on the platforms, even after adjusting for observed and unobserved covariates. Consequently, the study suggests that any policy aimed at the welfare of farmers should take participation in lifelong training programs of IPs into account.

1. Introduction

Agriculture is the primary source of income for many rural families in West Africa. The vast agricultural resource base in West

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Africa offers tremendous potential for expansion for both the rural sector and the whole economy [1]. Most importantly, its contribution to job generation cannot be overstated given that over 90 % of the population in West Africa depends on agriculture [[2,3]], and it supplies agro-related sectors with raw resources [4]. As a result, the sector has the potential advantage of promoting economic growth, eradicating poverty, and enhancing food security. However, the aforementioned potential of the sector could only be realized by raising the productivity of smallholder farmers [5]. Increasing agricultural production can boost rural incomes as well as access and availability of food. Unfortunately, the rural population in West Africa continues to be impoverished and unable to make essential investments in farm expansion due to the low income in rural areas [6]. Farmers are believed to be locked in the cycle of poverty due to their low agricultural output and productivity because of being unable to enhance their level of living [[7,8]]. Policymakers have used a wide range of ways to support agricultural development in underdeveloped nations to address these issues. Furthermore, West African countries and their development partners have long overlooked the critical roles of the sector in inclusive growth, food security, nutrition, and poverty alleviation, but this has changed in recent years [9]. Moreover, farmers in West Africa continuously strive to increase their agricultural output, food security, and revenue via increased stakeholder organization [[10,11]]. Also, development partners are more conscious of the value of participatory strategies for enhancing agricultural output. One of these participatory strategies is the innovation platform [12,13,9].

Of late, studies concentrated on understanding the concept of innovation platforms through their goals to accelerate the pace of technological progress [[14,15]]. A basis for the utilization of innovation platforms has developed from the application of previous multi-stakeholder research-for-development approaches, including local agricultural research committees, farmer field schools, exploratory research, learning alliances, and platforms for natural resource management [16]. Multi-stakeholder agricultural knowledge and information systems are now commonly referred to as "innovation platforms," which is the newest catchphrase in the method. Innovation platforms are interactive spaces created to facilitate knowledge-sharing and problem-solving among diverse stakeholders [[17,18,19]]. Innovation platforms, in their broadest sense, give development actors great latitude and flexibility to collaborate with interested parties to find urgent solutions [20]. Platforms for innovation are tactical tools for promoting agricultural system innovations [[21,22]] and encouraging collaboration for increased agricultural productivity [[23,24]], frequently focusing on excluded and underprivileged stakeholders [[23,25]]. Innovation platforms provide a forum for conversation and do not necessarily require a clear legal framework [26]. As such, they are not seen as consortia, which often require some sort of formal agreement between interested parties, but rather as conversational tools. Innovation platforms have a greater potential to identify innovations suitable for a given context than single-stakeholder groups of people with similar backgrounds and experiences, such as agricultural cooperatives, because they ideally include a variety of stakeholder types with different backgrounds and experiences for a common interest [[27,28]].

Multi-stakeholder solutions are increasingly valued by governments and non-governmental organizations in West Africa in order to achieve agricultural development and food security [[13,24,29]]. The use of multi-stakeholder forums in the agricultural research for development (AR4D) sector has increased in order to foster innovation and cooperation [[30,31,32]]. The potential benefit of this

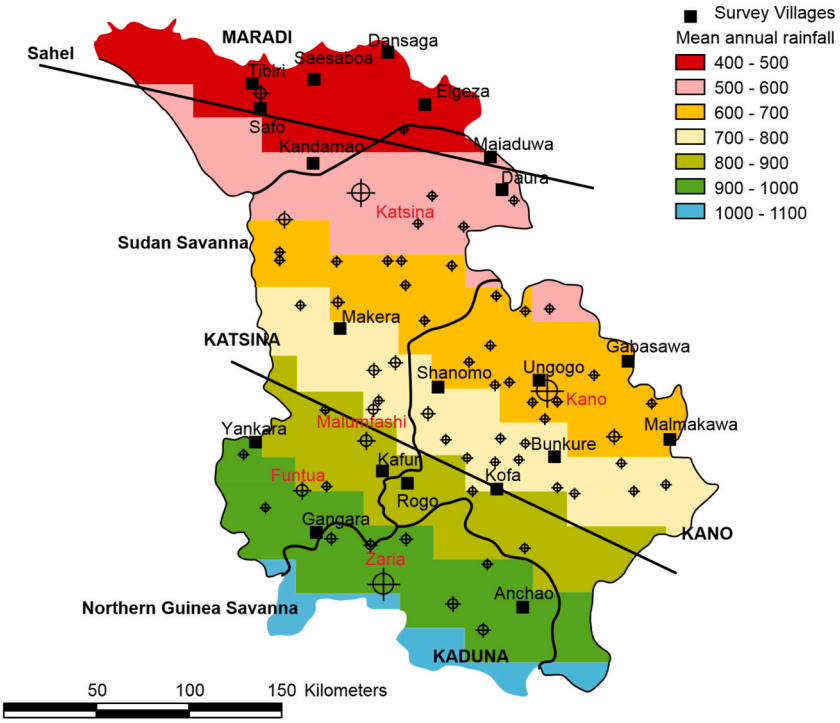

Fig. 1. Map of the Kano-Katsina-Maradi PLS

participatory technique in terms of influence on outcomes for the livelihood of rural smallholder farmers in Africa has been further demonstrated by previous research on innovation platforms-based agricultural interventions [[33,34,22]]. Despite the effectiveness of the multi-stakeholder platform strategy, studies on how it operates and how it might influence the outcome of its development are still mostly ongoing [[30,31,35,26]]. It is crucial to comprehend the different potential designs that enable innovation platforms to operate to reproduce successful innovation processes [17]. Thus, there is a lot of current interest in the ways that these multi-stakeholder systems support the growth of the agri-food chain and the pathways that influence different innovation platforms and their performance [[36,37]]. The AR4D sector encourages the use of multi-stakeholder innovation platforms, or IPs, as a means of bringing together diverse groups of people, often representing organizations, with a range of backgrounds, interests, and specializations, and providing a space for learning, action, and transformation [[38,3]]. Development organizations in sub-Saharan Africa are increasingly supporting multi-stakeholder innovation platforms (IP) in order to coordinate learning and action in this regard [[39,40]]. The urgent need for farmers to receive pertinent information from agricultural research and development in a timely manner is addressed by this coordination. With backing from the Commonwealth of Learning, it serves as a platform to enable farmers in West Africa to pursue lifelong learning (L3F).

The Commonwealth of Learning (COL) established L3F in response to the second Pan-Commonwealth Forum on Open Learning, which concentrated on open and distance learning (ODL) and information and communication technology (ICT) for agricultural development in low-income countries [41]. These efforts culminated in the L3F project proposal that was submitted to COL. The proposal aimed to collaborate with various international organizations such as the Food and Agricultural Organization (FAO), Consultative Group on International Agricultural Research (CGIAR), National Agricultural Research and Extension Systems (NARES), and others to tackle the long-term problems that smallholders in low-income countries encounter [42]. Avoiding top-down planning and one-way communication was a key component of the new approach of COL, which improved the standard of living for millions of smallholder farmers [43]. L3F seeks to guarantee a significant increase in education to meet the enormous learning needs that are present in developing nations [42]. To fulfil the goal of lifelong learning for farmers, COL coordinates technical efforts, provides money, and collaborates with stakeholders [[44,42]]. A collaboration of academic institutions with specializations in agriculture, veterinary and animal sciences, education, social sciences, open learning, technology, and agricultural research and development firms provides the course materials and contents to cater to the needs of rural communities. They also deliver the materials to the intended farmers when funding is needed. The target farmers are reached using audiovisual aids, mobile phones, internet service providers, and information and communication technology providers. The various stakeholders are active participants in a mutually beneficial arrangement [42]. Considering this, the L3F project is an effort to empower knowledge for rural development that results in secure livelihoods. In other words, L3F empowers and frees economically disadvantaged families by acquiring new information and skills that will help them become more productive farmers. The reason for this is that farmers decide on their wants and requirements while working with stakeholders to create a network [45]. Therefore, through appropriate and effective training systems, COL and its partners created strategies to employ ICTs to enhance L3F and thereby contribute to improved livelihoods for farmers [[44,46,47,48]].

Efficient training systems such as L3F are important to lift farmers out of poverty and increase their income. Training is a form of education that calls for more than just the dissemination of information or the acquisition of skills [[49,50,51,52]]. Agricultural training has the potential to be an efficient method of distributing pertinent new technology to increase productivity and decrease rural poverty [[53,54,55]]. Training boosts the income of farmers, but its knock-on effects boost the income of other players in the agricultural value chain as well [[56,55]]. Studies on the impact of training on agricultural productivity have been conducted in developing countries, with Tanzanian studies being among them [[57,57,58,59,60]]. Furthermore, agricultural training has typically been utilized to get around barriers to adopting agricultural technologies [[61,5,62,63,19]]. Numerous studies have also been done on how training affects agricultural production [[64,65,66,67]]. However, there is currently a dearth of studies that have investigated the link between farmers' training and their general well-being in the literature. Following the identification of the gaps in empirical research, the recommendations of [[68,69,70,71]], and the significance of additional investigations, we examine the mediated impact of IP training on farm income in West Africa in this study.

Specifically, this study investigated the impact of networking and training on farm income. Our research adds to the body of knowledge and discussion surrounding lifelong learning by demonstrating the following. First, we extend the efforts of previous studies by analyzing the relationship between innovation platforms' training and farm income. Second, we examine the determinants of membership of IPs among farmers. Third, we consider the determinants of participation in innovation platforms' training among farmers. Fourth, the way the outcome variable is constructed is equally crucial. Our outcome variable is farm income. Our definition of farm income takes into account sales of less-dominant crops and agricultural byproducts, which are typically disregarded in previous studies, in addition to sales of dominant crops and livestock products. Finally, to corroborate our conclusions, we present factual and qualitative data from various studies on innovation platforms. Despite being helpful in developing policy, these contributions are uncommon in the literature. Consequently, this will shed light on the impact of networking and training on farm income, allowing policymakers to better help farmers as they switch from subsistence to commercial agriculture. Our empirical study shows participation in innovation platforms has a positive impact on farm income when they participate in educational programs organized in the innovation platforms. Nevertheless, the findings of the study are restricted to West Africa. The same research ought to be promoted in other nations and economic situations. The following is the arrangement of the remaining sections of the paper: The material and methods are described in Section 2. The results and discussion are presented in Section 3, and the conclusions and suggested policies are presented in Section 4.

2. Material and methods

2.1. Area of study

This study was conducted in West Africa (Fig. 1). The rationale for choosing West Africa is based on the fact that learning sites for innovation platforms started in the region. Three Pilot Learning Sites (PLS) were used by the SSA CP to evaluate if multi-stakeholder approaches could provide bigger quantities of impact. These locations have been evaluated as benchmarks for various geographic regions of Africa. The regions are the Zimbabwe-Mozambique-Malawi axis, which serves as a sample site for Southern Africa; the Kano-Katsina-Maradi region, which serves as a representative site for West Africa; and the Lake Kivu region, which serves as a representative site for East and Central Africa. The Kano, Katsina, and Maradi (KKM) PLS, which covers 83,900 sq km, contains parts of Nigeria and the Niger Republic, and is home to over 18.3 million people, is the source of the study that is being presented here. The Innovation Platform (IP) served as the framework for the SSA CP's implementation of the Integrated Agricultural Research for Development (IAR4D) program. The Innovation Platform is an in-person and/or online forum that unites all possible innovation actors, from the commodity chain to the value web of the system, who are essential for the creation of innovation for a commodity or system of focus. It also facilitates continuous dialogue and cooperative learning about the advancement of innovation within the value web of the system or commodity chain.

In order to facilitate the easy delivery of the three capitals—human, financial, and social—necessary for innovation and, ultimately, the derivation of socioeconomic benefits, Innovation platform (IP) brings everyone into play. The process of IP establishment in the KKM was started with the first KKM PLS meeting, which was held in Kano in March 2005. A Pilot Learning Team (PLT) was formed during this conference to tackle the top concerns found in KKM communities. The PLT was made up of members from a wide range of scientific fields, including biophysical and social sciences, as well as organizations, including universities, CGIAR Centers, national agricultural research institutes, advanced research institutes, extension services, non-governmental organizations, community-based and farmers' organizations, and the private sector. The PLT put together a team under the direction of IITA to carry out validation research for limits and possible entrance sites in each of the three KKM agroecological zones. This committee, which included representatives from research, extension, nongovernmental organizations (NGOs), the private sector, and other institutions, was assembled to assess the situation at four levels: community, area, state, and region. A significant portion of the time was spent at the community level; they worked in 20 villages selected to be typical of the PLS using participatory methods.

Studies along similar lines have been conducted in other PLSs in Southern, Central, and East Africa. The application of the SSA CP in the Western African sub-region (PLS) is covered in this study. The project is situated along the Kano-Katsina-Maradi Republican axis, which connects Nigeria and Niger. Three Task Forces (TFs, Table 1) are involved in this project, which are as follows.

(i) "Multi-stakeholder strategy to combining technical choices, policy, and market access for better land productivity in the Northern Guinea Savanna zone" is the topic of discussion in the Northern Guinea Savanna.
(ii) The theme of Sudan Savanna TF is "Sustainable agricultural intensification and integrated natural resource management in the Sudan Savanna in West Africa."
(iii) To "improve rural people's livelihoods through intensification, market access, and sustainable management of natural resources in the Sahel agroecological zone" is the stated goal of the Sahel Savanna TF.

Each of the three TFs has approved research entrance sites, and these are.

(i) identifying and promoting the best agricultural storage techniques, integrated pest management (IPM), and indigenous knowledge systems (IKS).
(ii) Promotion of labor-saving technologies such as processing equipment and traction.
(iii) Coordinated soil fertility management.
(iv) Integrated crop-livestock production.

Table 1
Platforms for Innovation and task forces in the Kano-Katsina-Maradi Pilot learning site.

Taskforces	IP Crops	LGAs (district)	State	Country
Northern Guinea Savanna	Maize-legumes	Ikara	Kaduna	Nigeria
	Vegetable	Kudan		
	Livestock	Kubau		
	Rice	Dandume	Katsina	
Sudan Savanna	Maize-legumes-livestock	Bunkure	Kano	Nigeria
	Sorghum-legumes-livestock	Shanono		
	Maize-legumes-livestock	Musawa	Katsina	
	Sorghum-legumes-livestock	Safana		
Sahel savanna	Groundnut	Madarounfa	Maradi	Niger republic
	Cereal-legumes	Guidea Roumdji		
	Vegetables	Aguie		
	Livestock	Zango Daura	Katsina	Nigeria

(v) The promotion of appropriate crop varieties, such as pest-resistant, drought-tolerant, and early-maturing ones.
(vi) Using the appropriate technologies to increase irrigation potential.

The tasks undertaken by the task forces are designed with the intention of creating a framework that will suitably capture the main idea of the IAR4D. The introduction mentioned that the IAR4D implementation is structured within an IP system, which directs the selection of project locations according to the distinct features of each farming system of TF.

2.2. Sample selection

About 1800 households in the KKM PLS were chosen for this study. Under the auspices of the SSA CP, TFs carried out the survey with funding from the governments of Norway and Italy, the European Union (EU), and the UK Department for International Development (DfID). Selected from a small number of districts, the sample frame represented the three primary functional areas of the TFs in the KKM PLS. A random sample of each district's wards and a random sample of households in each chosen village were used to select representative homes in each district. If a household was part of one of the 180 villages selected from the clean, conventional, or IP/action sites, it was retained in the sample. Clean villages had no government presence, neither did conventional villages have ongoing programs using conventional methods; action sites, on the other hand, had established Innovation Platforms where learning with ODL/ICT was used to supplement financial and social/agribusiness capital. Banks and other financial institutions participate in the activities of the Platform but members provide the majority of the financial capital, while a wide range of partners offer specialized services in the areas of research, policy, marketing, agrochemicals, processing, storage, bulking, transportation, and seeds and other agribusiness-related resources provide the social and agribusiness capital.

2.3. Data analysis

This study examines the impact of innovation platform membership on farm income in West Africa. Descriptive statistics were first used to describe the data in order to better understand the socioeconomic characteristics of the farmers. The data were further investigated using the mediation technique to address the problems of unobserved heterogeneity and potential endogeneity.

2.3.1. Probit model

The probit regression model was used to examine the variables influencing membership in innovation platforms and participation in innovation platforms' training. It is anticipated that a farmer will choose whether or not to participate in innovation platforms' training that will increase his farm income. Using binary choice models, such as the probabilistic regression model (probit model) or the logistic regression model, the choice of farmers is approximated (logit model). The probit model was used in this study because it addresses the issue of heteroscedasticity [72]. The structure of the probit model is as follows: The probit model assumes that the dependent variable Y has two possible outcomes, 0 and 1, both of which are influenced by the independent variables X:

$$\Pr(Y = 1 / X) = \varphi(X'\beta) \tag{1}$$

The probability is denoted by Pr, and φ represents the cumulative distribution function of the standard normal distribution. The maximum likelihood estimate is used for the parameters (β). The probit model is shown as:

$$Y = F(\alpha + \beta xi) = F(zi) \tag{2}$$

Where Y = dependent variable.
F = function of the cumulative distribution
β = a parameter vector
x = independent variable vector
z = Z-value for βx.
The marginal effect of the variables is calculated using the formula:

$$\text{Marginal effects} = B_i \, Ø \, (Z) \tag{3}$$

In this case, the mean dependent variable from the probit estimation is associated with Ø (Zs), the cumulative normal distribution value, and B*i*s are the coefficients of the variables.

2.3.2. Mediation analysis

The study aims to investigate the impact of networking and training in Innovation Platforms on farm income. It is feasible for households to self-select into innovation platforms because our analysis is based on household survey data, which prohibits randomly selecting households to join or not join innovation platforms. Households self-select (i.e., based on socioeconomic and demographic factors) to determine whether to participate in an innovation platform, raising the possibility of endogeneity in an econometric estimation. Estimates of the impact of participation in innovation platforms may also be biased due to self-selection resulting from both observable and unobservable factors. Previous research has employed a number of strategies, including the endogenous treatment regression model [73], the inverse probability weighted regression adjustment (IPWRA) estimator [53], the propensity score matching (PSM) technique [74], and the endogenous switching probit (ESP) model [53], to reduce this bias. We estimate the effect of networking

and training in Innovation Platforms on farm income using meditation analyses. The meditation analyses have two noteworthy features: first, it is better to use this model than the PSM and IPWRA methods, which only take observable bias into account, as it can address selection bias from both observable and unobservable factors [[75,76]]. Second, participation in training programs in the innovation platforms, simulates the process by which membership in the innovation platform impacts farm income.

Mediation analysis is a frequent causal occurrence in statistical literature [[77,78,79]]. The goal of mediation analysis is to separate the effects of the average treatment on the outcome into two categories: effects that come directly from the influence of treatment on the outcome and effects that come indirectly from it. The foundation of previous approaches to mediation analysis was a form of structural equation modelling that relies on the specifications of systems of equations with parameters and variables to try and capture behavioral relationships and specify causal links between variables that were not derived from a formal framework for causal inference. These approaches assert that mediation analysis attempts to quantify the impact of a treatment that employs a particular mechanism rather than merely determining average treatment effects and does not allow sensitivity testing for identification assumptions [[80,79]]. According to mediation analysis (participation in IP training), farm income (outcome) is influenced by membership in innovation platforms (treatment) through a mediator.

It is hypothesized that membership in innovation platforms influences participation in innovation platforms' training and that this effect cascades causally to farm income. Economic experts are more concerned with calculating causal effects than mere relationships between variables, according to [[80,81,82,83]] identified the production function and sources of output impacts to provide an economically driven explanation of treatment effects. The concept of a causal effect states that changing the cause consistently changes the result. Mediation analysis is specified by three sets of equations to explain the pathway between cause (treatment) and outcome through a mediator. The equations are presented as

$$Y = cX + e_1 \tag{4}$$

$$M = aX + e_2 \tag{5}$$

$$Y = bM + c'X + e_3 \tag{6}$$

The model depicts a causal chain in which a mediator mediates an indirect effect of membership in innovation platforms on farm income (Participation in the innovation platforms training). Following [82], we define IP membership as the independent variable, farm income as the outcome, and training on innovation platforms as the mediator for this analysis.

However, it will be challenging to show causal effects or causal mediated effects in non-experimental research utilizing observational data because the treatment and mediator are not randomly assigned to the farmers [84]. suggested using sensitivity analysis to determine causal mediation effects in the absence of an instrumental variable. To establish causal mediation effects, following the framework created by Ref. [85], suggesting a causal mediation analysis using an instrumental variable for the treatment and mediation variables. The following causal relations can be specified for the model under linearity and using an instrument Z:

$$Z = \epsilon_Z \tag{7}$$

$$T = \beta_T^Z \times Z + \in_T \tag{8}$$

$$M = \beta_M^T \times T + \in_M \tag{9}$$

$$Y = \beta_Y^T \times T + \beta_Y^M \times M + \in_Y \tag{10}$$

Z = instrumental variable; T = treatment variable; M = mediation variable; Y = outcome variable
Equations (6)–(9) can be generally specified as $X = \Psi \times X + \in$ in (10) below

$$\underbrace{\begin{bmatrix} Z \\ T \\ M \end{bmatrix}}_{X} = \underbrace{\begin{bmatrix} 0 & 0 & 0 & 0 \\ \beta_T^Z & 0 & 0 & 0 \\ 0 & \beta_M^T & 0 & 0 \\ 0 & \beta_Y^T & \beta_Y^M & 0 \end{bmatrix}}_{\Psi} \underbrace{\begin{bmatrix} Z \\ T \\ M \end{bmatrix}}_{X} \underbrace{\begin{bmatrix} \epsilon_Z \\ \epsilon_T \\ \epsilon_M \end{bmatrix}}_{\epsilon} \tag{11}$$

The covariance matrix Σ_X of the observed variables is shown in equation (12).

$$\Sigma_X \equiv Var \begin{pmatrix} Z \\ T \\ M \\ Y \end{pmatrix} = \begin{bmatrix} \sigma_{ZZ} & \sigma_{ZT} & \sigma_{ZM} & \sigma_{ZY} \\ \bullet & \sigma_{TT} & \sigma_{TM} & \sigma_{TY} \\ \bullet & \bullet & \sigma_{MM} & \sigma_{MY} \\ \bullet & \bullet & \bullet & \sigma_{YY} \end{bmatrix} \tag{12}$$

$\in$ will represent the covariance matrix of the unobserved error terms $\Sigma_{\in}$. Since Z is an IV, it applies that ϵ_Z is statistically independent of ϵ_T; ϵ_M; ϵ_Y: Thus, $\Sigma_{\in}$ is given by

$$\Sigma_{\in} \equiv Var\begin{pmatrix} \epsilon_Z \\ \epsilon_T \\ \epsilon_M \\ \epsilon_Y \end{pmatrix} = \begin{bmatrix} \sigma^2_{\epsilon Z} & 0 & 0 & 0 \\ \bullet & \sigma^2_{\epsilon T} & \rho_{TM\sigma_{\epsilon T}\sigma_{\epsilon M}} & \rho_{TY\sigma_{\epsilon T}\sigma_{\epsilon Y}} \\ \bullet & \bullet & \sigma^2_{\epsilon M} & \rho_{MY\sigma_{\epsilon M}\sigma_{\epsilon Y}} \\ \bullet & \bullet & \bullet & \sigma^2_{\epsilon Y} \end{bmatrix} \tag{13}$$

Following [85], a causal mediation model with an instrumental variable was used to ascertain how training participation affected farm income in the study area. This model does not call for an exogenous mediator or a separate instrumental variable for the mediator. The model, often known as a "double" 2SLS model, was described as follows:

$$First\ stage{:}T{=}\beta^Z_T \times Z{+}\in_T \tag{14}$$

$$Second\ stage{:}M{=}\beta^T_M \times \widehat{T}{+}\in_M \tag{15}$$

Where the predicted treatment, $\widehat{T}$, (membership in IPs) was estimated from the first equation and M is the mediation variable (participation in IPs training) and Z is the instrumental variable (access to extension services).

$$Fisrst\ stage{:}M{=}\gamma^Z_M \times Z{+}\gamma^T_M \times T{+}\in_T \tag{16}$$

$$Second\ stage{:}Y{=}\beta^M_Y \times \widehat{M}{+}\beta^T_Y \times T{+}\in_Y \tag{17}$$

Where the predicted mediation variable, $\widehat{M}$, (participation in IPs training) was estimated from the first equation of the second part and Y is the farm income.

Using the Stata immediate function [85], calculated the causative mediation analysis with an instrumental variable. Weak identification was tested for in the first two stages (13) and (14) of this "double" 2SLS causal mediation analysis using the associated F-statistics on the omitted instruments. If robust or cluster-robust standard errors were required for the model, the F-statistic proposed by Ref. [86] is used. According to a general principle, an F-test of the instrument(s) that were previously discarded should produce an F-statistic of 10 or higher [87].

Next, we employed the Z-test, also known as the Sobel test, to determine the significance of the mediation effect. Specifically, if the absolute value of Z mediation in Equation (21) is higher than 1.96 (for two-tailed tests with $\alpha = 0.05$), then the mediation effect is significant [88].

$$Z_a = \frac{a}{Z_a} \tag{18}$$

Table 2
Descriptive statistics of sampled farmer.

Variables	Description	Mean	SD	Percentage
Gender	1 = if the respondent is male			88
Age	Age of the respondents in years	46.83	15.01	
Marital Status	1 = If a respondent is married			51
Education	Years of formal education	3.69	2.63	
Household size	The count of people living in a household	9.20	8.61	
Farming experience	Average years of farming experience	28.38	9.72	
Male working-class members	The count of males in a household who are between the ages of 16 and 58	2.13	1.65	
Female working-class members	The count of females in a household who are between the ages of 16 and 58	2.08	1.40	
Young dependents	The count of people under 16 living in a household	4.02	3.69	
age dependents	The count of individuals in a household who are older than 59	1.06	0.49	
Agricultural extension	1 = If a respondent is visited by an extension agent			39
IP membership	1 = If a respondent participates in IP			72
Numbers of training	The number of farmer trainings that they attended	16.16	4.02	
Income	The monthly farm income of the farmer	11531	1570	

$$Z_b = \frac{b}{Z_b} \tag{19}$$

$$Z_{a\times b} = Z_a \times Z_b \tag{20}$$

$$Z_{meditation} = \frac{Z_{a\times b}}{SE(Z_{a\times b})} = \frac{Z_a \times Z_b}{\sqrt{Z_a^2 + Z_b^2 + 1}} \tag{21}$$

3. Result and discussion

3.1. Socio-economics characteristics of the farmers

A description of the socioeconomic characteristics of the farmers in the study area is presented in Table 2. The age of farmers is a significant factor in determining their participation in innovation platforms. The respondents in the study area are 46 years old on average. This indicates that the average farmer in the study area is still economically active. The outcome is consistent with the findings of [[89,53]]. Most farmers (88 %) are men. This demonstrates that men are more involved and active in farming operations in West Africa. The results corroborate those of [90]. Married farmers comprise approximately 51 % of the population. This supports the idea that farming is essentially a family business run by farm households, where each spouse assists in the farming operation to reduce labor expenses. This outcome is consistent with the findings of [91]. The average length of schooling in the area of study is Four years. This implies that literate farmers are not involved in agricultural production in West Africa. This result runs counter to what [92] articulated. The years of average farming experience among the farmers in the study area is 28 years. That implies a high level of farming expertise on the part of the farmers. This substantiates previous discoveries made by different researchers, including [[91, 93]]. Nine persons make up an average household in the study area. Since they seem to have large households as a result, the farmers in the study area may serve as a buffer against labor shortages. The outcome is consistent with [94]. Extension agents visited about 39 % of the respondents during the last production season. The membership of agricultural innovation platforms influences the decision to adopt improved technologies. About 72 % of the respondents are members of the agricultural IP. This facilitates farmer-to-farmer connections to share information. Farmers have, on average, attended sixteen IP trainings. This might encourage farmers to adopt newly introduced innovations. In the study, the average monthly income is ₦11531. The outcome implies that the adoption of better technologies is feasible when capital is available.

3.2. Determinants of membership in innovation platforms

Table 3 presents the results of the probit regression model for membership in the innovation platform. Based on the Wald Chi2 (10) of 43.96 and statistical significance of 1 %, along with a log pseudo-likelihood of −1805.2969 and pseudo-R^2 of 0.0120, the results of Table indicate that the model provides a good fit. The findings suggest the significant influence of marital status, education, household size, farming experience, and the proportion of working-class males and females, and young dependents on the decision to join the innovation platform. Marital status (0.150) has a positive and significant coefficient. This suggests that there is a positive relationship between married status and innovation platform membership. According to the marginal effect, a 1 % increase in marital status will most likely result in a 5.4 % increase in innovation platform membership. This suggests that farmers who are married have a higher likelihood of using innovation platforms. This is probably because couples pool their resources to support their rising household and farm expenses, which makes them more and more dependent on outside assistance such as assistance from innovation platforms [95].

Table 3
Probit regression estimates of determinants of membership in Innovation platforms.

Variables	Co-efficient	t-ratio	Marginal effects	t-ratio
Gender	0.170 (0.110)	1.55	0.063(0.041)	1.51
Age	0.224(0.192)	0.12	0.080(0.069)	0.12
Marital Status	0.150(0.041)	3.59[a]	0.054(0.015)	3.59[a]
Education	0.406(0.101)	3.99[a]	0.014(0.003)	3.99[a]
Household size	−0.530(0.126)	−3.42[a]	−0.019(0.004)	−3.42[a]
Farming Experience	0.151(0.049)	3.61[a]	0.054(0.009)	3.61[a]
Male working-class members	0.379(0.114)	3.32[a]	0.012(0.004)	3.32[a]
Female working-class members	−0.206(0.124)	−2.68[a]	−0.074(0.043)	−2.68[a]
Young dependent	0.681(0.529)	3.02[a]	0.024(0.004)	3.02[a]
Aged dependent	−0.162(0.022)	−0.73	−0.058(0.007)	−0.74
Constant	0.124(0.093)	3.64[a]		
Wald chi2(10)	43.96			
Pseudo R2	0.012			
Log-likelihood test	−1805.2969			
Prob > chi2	0.0000			

Source: Forum for Agricultural Research in Africa report [a], [b], & [c] means the coefficients are significant at 1 %, 5 % and 10 %. Figures in parenthesis represent robust standard errors

At 1 %, the coefficient of education (0.406) is positive and significant. This indicates that participation in innovation platforms and education are positively correlated. According to the marginal effect, students who complete one more year of education will probably become 1.4 % more active on innovation platforms. This implies that farmers who read have a higher propensity to become IP members. This may be explained by the knowledge that knowledgeable farmers have the advantages of agricultural innovation platforms and the process of becoming a member. This is probably because farmers who are more literate and educated make better decisions to gain from participating in innovation platforms. Studies conducted by other researchers have also suggested that education has a positive impact on the decision of farmers to join agricultural cooperatives because it improves their comprehension of the logistics involved in innovation platforms. These results, however, are at odds with those by Ref. [96] which found that farmers with little formal education were more likely to join cooperatives to obtain the necessary knowledge and skills regarding agricultural issues, potentially leading to an increase in production.

The coefficient of household size (0.530) is negative and significant at 1 %. The membership in innovation platforms is therefore negatively proportionate to household size. The marginal effect suggests that an increase in the size of a single-person household will probably lead to a 1.9 % decrease in membership in innovation platforms. This implies that IPs are more likely to be joined by smaller households. This suggests that the fact that most of the respondents were married may support the idea that they were responsible and mature enough to participate in agriculture to a greater extent without needing outside assistance. This is probably because, in comparison to innovation platforms, larger farming households have more varied needs, which are generally easier to meet on other platforms [95]. This finding contradicts the findings of studies such as [[97,98]] asserted that labor is a scarce resource in agriculture and that household members must provide the labor for this purpose. The coefficient of farming experience (0.151) is positive and significant at 1 %. This indicates that participation in innovation platforms is positively correlated with years of farming experience. The marginal effect indicates that one more year of farming experience will likely result in a 5.4 % increase in membership in innovation platforms. This suggests that more seasoned farmers are more likely to sign up for membership in innovation platforms. The results show the highest odds rating which depicts that farmers with more years of experience engaged in innovation platforms at a higher rate. This could be because they have acquired more knowledge and skills over the years, and they will adopt innovations that will help boost their production [99].

There is a significant and positive correlation between the number of male members from the working class (0.379). This suggests a positive relationship between the proportion of male members from the working class and participation in innovation platforms. The marginal effect indicates that an increase of one working-class male member will likely result in an increase of 7.4 % in membership in innovation platforms. This implies that IPs are more likely to be joined by households with a high percentage of working-class male members. According to this finding, male members of working-class households are likely to be more open to participating in innovation platforms. This result corroborates the findings of other studies, including [[97,98]]. At 1 %, the coefficient of the number of working-class female members (0.206) is significant and negative. It can be inferred that there is an inverse relationship between the membership of innovation platforms and the proportion of working-class women. The marginal effect indicates that an increase of one working-class female member will likely result in a 7.4 % decrease in membership in innovation platforms. This suggests that working-class households with a small proportion of female members are more likely to become IP members [[100,101]]. This is explained by the possibility that working-class households with a high proportion of female members may be compelled to shift a portion of their labor force to non-farm pursuits in an effort to increase income and reduce the pressure on consumption brought on by a sizable number of dependent children. This result is consistent with the studies of [92]. At 1 %, the coefficient of young dependents (0.162) is both positive and significant. This suggests that there is a positive correlation between the number of young dependents and the membership of innovation platforms. According to the marginal effect, there will probably be a 2.4 % increase in innovation platform membership for households with more young dependents. This implies that the likelihood of IP membership is higher for households with a large percentage of young dependents. This suggests that a rise in household size will result in a corresponding rise

Table 4
Probit regression estimates of determinants of participation in Innovation Platforms' training.

Variables	Co-efficient	t-ratio	Marginal effects	t-ratio
Gender	0.337(0.188)	2.79[a]	0.051(0.023)	2.75[a]
Age	−0.113(0.042)	−3.27[a]	−0.019(0.007)	−3.26[a]
Marital Status	0.502(0.073)	0.68	0.088(0.012)	0.68
Education	0.212(0.165)	3.28[a]	0.003(0.002)	3.28[a]
Household size	−0.703(0.263)	−2.27[b]	−0.012(0.004)	−2.27[b]
Farming Experience	−0.213(0.043)	−0.49	−0.037(0.007)	−0.49
Male working-class members	0.938(0.216)	3.44[a]	0.016(0.003)	3.44[a]
Female working-class members	−0.148(0.021)	−2.07[b]	−0.026(0.08)	−2.07[b]
Young dependent	0.934(0.126)	0.74	0.016(0.002)	0.74
Aged dependent	0.175(0.031)	4.55[a]	0.030(0.005)	4.55[a]
Constant	1.674(0.326)	5.13[a]		
Wald chi2(10)	41.64			
Pseudo R2	0.0921			
Log-likelihood test	629.0.364			
Prob > chi2	0.0000			

Source: Forum for Agricultural Research in Africa report [a], [b], & [c] means the coefficients are significant at 1 %, 5 % and 10 %. Figures in parenthesis represent robust standard errors.

in the number of people using innovation platforms. The findings of [102] are not consistent with this outcome.

3.3. Determinants of participation in IPs training

The outcome of the probit regression model for participation in training on innovation platforms is presented in Table 4. The Wald Chi^2 (10) value of 41.64, the statistical significance of 1 %, log pseudolikelihood of 629.0364, pseudo R^2 of 0.0921, and findings from the Table show that the model is a good fit. The findings of the model show that variables such as gender, age, years of education, household size, the proportion of working-class males and females, and the number of aged dependents have a significant impact on whether or not a person participates in training on innovation platforms. At 1 %, the gender coefficient (0.337) is significant and positive. This indicates that gender and participation in training on innovation platforms are positively correlated. The marginal effect shows that an increase in contact with male farmers by a person will probably increase participation in training on innovation platforms by 5.1 %. This implies a higher likelihood of male farmers participating in participation in training on innovation platforms. It is likely because farming involves more physical labor than other occupations. Accordingly, households headed by men are better physically suited to make agricultural investments than households headed by women. According to a related study by Ref. [103], male farmers are more likely than female farmers to take part in an agricultural innovation platform. Nonetheless, this bolsters the study of [[89,104,105,106]], who both linked the capacity of men to obtain and manage resources to the positive correlation between gender and participation. At 1 %, the coefficient of age (0.113) is significant and negative. This means that age has a negative relationship with participation in training on innovation platforms. The marginal effect shows that an increase in contact with older farmers by a person will probably decrease participation in training on innovation platforms by 1.9 %. This suggests that young farmers have a greater tendency to fully participate in training on innovation platforms. This may be explained by the fact that younger farmers typically possess superior conceptual qualities in terms of knowledge, attitudes, and skills compared to older farmers. The natural tendency to be curious and eager to try new things is very strong in young farmers. Stated differently, younger farmers are more likely than older farmers to take part in the training offered by innovation platforms because they are expected to search for innovations and agricultural information. This result is consistent with that of [[107,108]], who discovered that younger farmers in Kenya, Tanzania, and Uganda had higher participation rates in farmers' field school groups than older farmers did.

At 1 %, the coefficient of education (0.212) is significant and positive. This indicates that participation in training on innovation platforms is positively correlated with education. According to the marginal effect, a one-year increase in years of schooling will most likely result in a 0.3 % increase in participation in training on innovation platforms. This suggests that literate farmers are more inclined to take part in training on innovation platforms. A positive relationship between education and participation in innovation platforms' training may show that more literate farmers can understand and apply different sorts of training provided in innovation platforms which helps them to attend the training regularly. This is consistent with the study conducted by [[99,109,110]]. Literate farmers may comprehend meetings and training more readily than their illiterate counterparts, increasing their awareness of the opportunities presented by innovation platforms. It was, however, at odds with the results of [111], who suggested that the preference of those with higher levels of education for wage employment was the reason for the negative correlation between participation in training on innovation platforms and formal education. At 1 %, the coefficient of household size (0.212) is negative and significant. This implies that participation in training on innovation platforms is negatively correlated with household size. The marginal effect indicates that a one-person increase in household size will likely result in a 1.2 % decline in participation in training on innovation platforms. This implies that households with fewer members are more likely to participate in the training offered by innovation platforms. This might be explained by the possibility that household members work in non-agricultural fields, which prevents them from attending agricultural training programs. This outcome runs counter to [[89,61]].

At 1 %, the number of male members from the working class has a positive and significant coefficient (0.938). This means that the number of male members from the working class has a positive relationship with participation in training on innovation platforms. The marginal effect indicates that an increase of one male working-class member will most likely result in a 1.6 % increase in participation in training on innovation platforms. This suggests that the likelihood of joining innovation platforms and participating fully in their training is higher in households with a high percentage of male members from the working class. This suggests that respondents with a larger number of male members from the working class have more labour supply for participating in agricultural activities which may encourage them to engage in agricultural training. This aligns with the research conducted by [[112,113]]. At 1 %, the coefficient of the number of working-class female members (0.148) is significant and negative. This indicates that there is a negative correlation between the proportion of working-class female members and their involvement in training programs of innovation platforms. The marginal effect shows that an increase in the number of female members from the working class by a person will probably decrease participation in innovation platforms' training by 2.6 %. This suggests that working-class households with fewer female members are more likely to join innovation platforms and take advantage of the training opportunities of platforms. The argument stems from the fact that training married women with children requires more time investment if it is done outside of regular business hours. They are therefore less motivated to take part in those kinds of training programs. At 1 %, the coefficient of the number of aged dependents (0.175) is both positive and significant. This means that the number of aged dependents has a positive relationship with participation in training on innovation platforms. The marginal effect indicates that the number of aged dependents in a household will likely boost their participation in training on innovation platforms by 3.0 %. This suggests that households with a large number of elderly dependents are more likely to participate in the training offered by innovation platforms. The reasoning behind this is that older family members are probably more responsible, which could lead them to look for other sources of income. The results of [[109,100]] are also in line with this outcome.

3.4. Effects of membership in IPs and training on income of farmers

Table 5 presents the findings of a causal mediation analysis using an instrumental variable (IV) to examine the relationship between farm income and IP membership. The Wald test of exogeneity shows that the participation in training on innovation platforms is endogenous in Table 5. We used the access to extension services as an instrumental variable (IV). The so-called inclusion restriction—the IV—must have a strong correlation with training participation on the innovation platform. The F test for the excluded instruments in the first stage of the Kleibergen-Paap F-statistic is 12.144. This suggests that in this IV setting, there is no weak identification. With a probability value of 0.000 significance, the z-value of Sobel (39.073) is less significant than the 0.05 level. Thus, there was a notable partial mediation. There is a significant mediation of participation in innovation platforms' training in the relationship between membership in innovation platforms and farm income in West Africa. It cannot be claimed that membership in innovation platforms influences farm income because of training participation alone, as this is only a partial mediation. This indicates that participation in innovation platforms' training is one of the reasons why membership in innovation platforms can influence farm income.

According to the Sobel Z-test, the partial mediation area is not large enough. As a result, farm income is affected in a more conservative manner by the mediating effect of training participation in innovation platforms. It is conservative in the sense that it takes into consideration all social factors that affect farm income. But the partial mediation also translates that of the overall effect, with nearly 15 % attributed to extraneous factors not included in the model. Moreover, the high predictability of the regression models suggests that engagement in training programs offered by innovation platforms accounts for a significant amount of the variation of the dependent variables. This result has been supported by the study of [[62,114]]. We applied the MCMC method [115] and the distribution of the product method [116] to obtain more precise statistical tests and confidence limits. The product method distribution indicates a 15.23 mediation effect. The 95 % confidence intervals (3.23, 22.77) do not include 0. This means that membership in innovation platforms significantly affects the farm income as mediated by participation innovation platforms' training. Moreover, the distribution of product method and the MCMC method yield similar results. Consequently, the effect of membership in innovation platforms is significantly mediated by participation in their training programs.

The outcome equation (income) was modelled using Ordinary Least Square (OLS) regression, whereas the mediator equation (participation in innovation platforms' training) was modelled using probit regression. Through the use of mediation analysis, the overall impact of innovation platforms membership on farm income was divided into two categories: direct and indirect effects due to participation in innovation platforms' training. The results show a significant and positive relationship between membership in innovation platforms and income. The direct effect showed that membership in innovation platforms will increase the income of farmers by 77.5 %. When this total effect was decomposed into direct effects and indirect effects, it was revealed that close to 86 % of the total effect of membership in innovation platforms on the income of farmers was mediated by participation in innovation platforms' training. This result implies that membership in innovation platforms has most of its effect on farm income when they participate in educational programmes organized in innovation platforms. A plausible reason for this is that participation in educational programmes organized in innovation platforms aid farm investment which consequently has a positive effect on income. The anticipated benefit stems from the fact that training on the innovation platforms would help households boost their output by enhancing their capacity and offering technical information on various agronomic, animal health and husbandry, and natural resource conservation topics. The outcome is consistent with [117], which finds a positive connection between modular training and household welfare.

Table 5
Effects of membership in innovation platforms on income of farmers.

Training (Mediator) Equation	Coefficient	Standard Error	t-value
Membership in IP	1.546	0.360	6.94[a]
Income (Outcome Equation)			
Training received in IP	1.994	0.461	5.45[a]
Membership in IP	1.303	0.682	4.00[a]
Effect	**Mean**	**95 % Confidence Interval**	
Total effect	0.775	0.375	3.64[a]
Direct effect	0.994	0.241	2.37[a]
Indirect effect	0.788	0.395	2.48[a]
% of total effect mediated	85.68		
Kleibergen-Paap F-statistic for excluded instruments in			
First stage one (T on Z)	12.144		
First stage two (M on Z|T)	23.834		
Wald test of exogeneity	19.01[a]		
% of total effect mediated	85.68		
Excluded instrument (social benefit)			
Sobel z-value	39.973[a] p=<0.0000		
Distribution of the product	15.23 [3.23, 22.77]		
Markov Chain Monte Carlo	15.23 [3.18, 22.77]		

Data Source: Forum for Agricultural Research in Africa (FARA) Report [a], [b], & [c] means the coefficients are significant at 1 %, 5 % and 10 %. Figures in parentheses represent robust standard errors.

4. Conclusion and recommendations

This study investigated the impact of membership in innovation platforms and training on innovation platforms on farm income in West Africa. A multistage sampling procedure was used to collect data for the study. The data were analyzed using the probit and mediation model. The probit model showed that marital status, education, household size, farming experience, and the number of male working-class members, female working-class members and young dependents have a significant impact on the decision to join innovation platforms. Additionally, the results of the probit model show that the decision of farmers to take part in the training offered by innovation platforms is significantly influenced by factors such as gender, age, years of education, household size, and the proportion of male and female working-class individuals as well as elderly dependents. According to the mediation analysis, membership in the innovation platform and farm income have a robust and positive relationship. The direct effect showed that membership in innovation platforms will increase the income of farmers by 77.5 %. When this total effect was decomposed into direct effect and indirect effect, it was revealed that close to 86 % of the total effect of membership in innovation platforms on the farm income was mediated by participation in training on innovation platforms. Farmers should thus be encouraged to join innovation platforms in order to network, and more awareness-raising efforts should be made to boost the number of farmers who take part in the training programs offered by the innovation platforms. Policymakers must take into account various factors, including age, marital status, education level, household size, farming experience, and the presence of both male and female working-class members, when deciding whether to enroll a household in IP training. This should be a crucial component of any initiative designed to promote household participation in innovation platforms' training. Therefore, the policy recommendation is that older farmers with sizable households should be reintroduced to adult education packages on the advantages of membership in innovation platforms.

CRediT authorship contribution statement

Adeolu B. Ayanwale: Writing – review & editing, Writing – original draft, Supervision, Conceptualization. **Adewale A. Adekunle:** Writing – review & editing, Conceptualization. **Ayodeji D. Kehinde:** Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Fatunbi A. Oluwole:** Writing – review & editing, Project administration, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] K.E. Giller, T. Delaune, J.V. Silva, K. Descheemaeker, G. van de Ven, A.G. Schut, M.K. van Ittersum, The future of farming: who will produce our food? Food Secur. 13 (5) (2021) 1073–1099.
[2] H. Björklund, A. Parkkinen, T. Hakkari, R.K. Heikkinen, R. Virkkala, A. Lensu, Predicting valuable forest habitats using an indicator species for biodiversity, Biol. Conserv. 249 (2020), 108682.
[3] World Bank, Enhancing Agricultural Innovation: How to Go beyond the Strengthening of Research Systems, vol. 135, The International Bank for Reconstruction and Development/The World Bank, Washington DC, USA, 2006.
[4] A.D. Kehinde, Access to trade credit and its impact on the use of European Union (EU) approved pesticides among smallholder cocoa farmers in Ondo State, Nigeria, Heliyon 8 (12) (2022), e12409.
[5] B.A. Awotide, A.D. Alene, T. Abdoulaye, V.M. Manyong, Impact of agricultural technology adoption on asset ownership: the case of improved cassava varieties in Nigeria, Food Secur. 7 (6) (2015) 1239–1258.
[6] T. Mogues, C. Marc, B. Regina, L. Mamusha, R. Josee, T. Fanaye, P. Zelekawork, Agricultural Extension in Ethiopia through a Gender and Governance Lens, 2009. International Food Policy Research Institute ESSP2 Discussion Paper 007. Available online: http://www.ifpri.org/publication/. (Accessed 5 December 2012). agricultural-extension-ethiopia-through-gender-and-governance-lens.
[7] R. Adeyemo, A.D. Kehinde, Community driven development: the case of fadama II cooperatives in alleviating poverty in a developing country, Contemp. Agric. 70 (1–2) (2021) 46–53.
[8] A.D. Kehinde, R. Adeyemo, A.A. Ogundeji, Does social capital improve farm productivity and food security? Evidence from cocoa-based farming households in Southwestern Nigeria, Heliyon 7 (3) (2021), e06592.
[9] G. Téno, J.J. Cadilhon, Capturing the impacts of agricultural innovation platforms: an empirical evaluation of village crop-livestock development platforms in Burkina Faso, Livest. Res. Rural Dev. 29 (9) (2017).
[10] Putting heads together, in: S. Nederlof, M. Wongtschowski, F. van der Lee (Eds.), Agricultural Innovation Platform in Practice, KIT Publishers, Amsterdam, the Netherlands, 2011.
[11] World Bank, Agricultural Innovation Systems: an Investment Sourcebook, World Bank, Washington, D.C, 2012 from, http://siteresources.worldbank.org/INTARD/Resources/335807-1330620492317/9780821386842.pdf. (Accessed 11 March 2017).
[12] J. Cadilhon, A conceptual framework to evaluate the impact of innovation platforms on agrifood value chains development, in: Paper Prepared for the 138th EAAE Seminar on Pro-poor Innovations in Food Supply Chains, Ghent, Belgium, September 11–3, 2013, 2013.
[13] B. Cullen, J. Tucker, K. Snyder, Z. Lema, A. Duncan, An analysis of power dynamics within innovation platforms for natural resource management, Innovation and Development 4 (2014) 259–275, https://doi.org/10.1080/2157930X.2014.921274, from. (Accessed 11 March 2017).
[14] M.P. Hekkert, S.O. Negro, Functions of innovation systems as a framework to understand sustainable technological change: empirical evidence for earlier claims, Technol. Forecast. Soc. Change 76 (2009) 584–594.
[15] W. Kanda, P. del Río, O. Hjelm, D. Bienkowska, A technological innovation systems approach to analyse the roles of intermediaries in eco-innovation, J. Clean. Prod. 227 (2019) 1136–1148.
[16] M. Schut, J.J. Cadilhon, M. Misiko, I. Dror, The state of innovation platforms in agricultural research for development, in: I. Dror, J.-J. Cadilhon, M. Schut, M. Misiko, S. Maheshwari (Eds.), Innovation Platforms for Agricultural Development: Evaluating the Mature Innovation Platforms Landscape, Routledge, Oxon, United Kingdom, and New York, 2016, pp. 1–15, from, https://cgspace.cgiar.org/handle/10568/68755. (Accessed 11 March 2017).

[17] S. Homann-Kee Tui, A. Adekunle, M. Lundy, J. Tucker, E. Birachi, M. Schut, L. Klerkx, P.G. Ballantyne, A.J. Duncan, J.J. Cadilhon, P. Mundy, *What Are Innovation Platforms?* Innovation Platforms Practice Brief no.1, International Livestock Research Institute (ILRI), Nairobi, 2013 from, https://cgspace.cgiar.org/handle/10568/34157. (Accessed 11 March 2017).

[18] K. Knickel, G. Brunori, S. Rand, J. Proost, Towards a better conceptual framework for innovation processes in agriculture and rural development: from linear models to systemic approaches, J. Agric. Educ. Ext. 15 (2) (2009) 131–146, https://doi.org/10.1080/13892240902909064.

[19] G. Mgendi, S. Mao, F. Qiao, Does agricultural training and demonstration matter in technology adoption? The empirical evidence from small rice farmers in Tanzania, Technol. Soc. 70 (2022), 102024.

[20] H. Ngwenya, J. Hagmann, Making innovation systems work in practice: experiences in integrating innovation, social learning and knowledge in innovation platforms, Knowl. Manag. Dev. J. 7 (2011) 109–124.

[21] E.S. Nederlof, R. Pyburn, One Finger Cannot Lift a Rock: Facilitating Innovation Platforms to Trigger Institutional Change in West Africa, Royal Tropical Institute, Amsterdam, 2012.

[22] M. Schut, L. Klerkx, M. Sartas, D. Lamers, M.M. Campbell, I. Ogbonna, P. Kaushik, K. Atta-Krah, C. Leeuwis, Innovation platforms: experiences with their institutional embedding in agricultural research for development, Exp. Agric. 52 (2015) 537–561, https://doi.org/10.1017/S001447971500023X, from. (Accessed 11 March 2017).

[23] M. Seifu, A. van Paassen, L. Klerkx, C. Leeuwis, A State-Initiated Multi-Stakeholder Platform as an Instrument to Build Agricultural Innovation System Capacity: a Case Study from Ethiopia, Innovation and Development, 2022, pp. 1–22.

[24] A. Van Paassen, L. Klerkx, R. Adu-Acheampong, S. Adjei-Nsiah, E. Zannoue, Agricultural innovation platforms in West Africa. How does strategic institutional entrepreneurship unfold in different value chain contexts? Outlook Agric. 43 (2014) 193–200.

[25] K. Swaans, B. Boogaard, R. Bendapudi, H. Taye, S. Hendrickx, L. Klerkx, Operationalizing inclusive innovation: lessons from innovation platforms in livestock value chains in India and Mozambique, Innovation and Development 4 (2) (2014) 239–257.

[26] A. van Paassen, L. Klerkx, R. Adu-Acheampong, S. Adjei-Nsiah, B. Ouologuem, E. Zannou, P. Vissoh, L. Soumano, F. Dembele, M. Traore, Choice-making in facilitation of agricultural innovation platforms in different contexts in West Africa: experiences from Benin, Ghana and Mali, Knowl. Manag. Dev. J. 9 (2013) 79–94, from, http://journal.km4dev.org/index.php/km4dj/article/viewFile/156/257. (Accessed 11 March 2017).

[27] D. Horton, B. Akello, L. Aliguma, T. Bernet, A. Devaux, B. Lemaga, D. Magala, S. Mayanja, I. Sekitto, G. Thiele, C. Velasco, Developing capacity for agricultural market chain innovation: experience with the "PMCA" in Uganda, J. Int. Dev. 22 (2010) 367–389.

[28] X. Yin, J. Chen, J. Li, Rural innovation system: revitalize the countryside for a sustainable development, J. Rural Stud. 93 (2022) 471–478.

[29] World Bank, World Development Report 2008: Agriculture for Development, World Bank, Washington, D.C, 2008 from, https://openknowledge.worldbank.org/handle/10986/5990. (Accessed 11 March 2017).

[30] I. Dror, J.J. Cadilhon, M. Schut, M. Misiko, S. Maheshwari, Innovation Platforms for Agricultural Development. Evaluating the Mature Innovation Platforms Landscape, Routledge, Oxon, United Kingdom, and New York, 2016 from, https://cgspace.cgiar.org/handle/10568/68755. (Accessed 11 March 2017).

[31] R. Lema, E. Kraemer-Mbula, M. Rakas, Innovation in developing countries: examining two decades of research, Innovation and Development 11 (2–3) (2021) 189–210.

[32] A. Neef, D. Neubert, Stakeholder participation in agricultural research projects: a conceptual framework for reflection and decision-making, Agric. Hum. Val. 28 (2) (2011) 179–194.

[33] M.A.T.J. Mapila, J.F. Kirsten, F.H. Meyer, The impact of agricultural innovation system interventions on rural livelihoods in Malawi, Dev. South Afr. 29 (2011) 303–315.

[34] K. Nyikahadzoi, P. Pali, A.O. Fatunbi, L.O. Olarinde, J. Njuki, A.O. Adekunle, Stakeholder participation in innovation platform and implications for integrated agricultural research for development (IAR4D), Int. J. Agric. For. 2 (2012) 92–100, from, http://article.sapub.org/10.5923.j.ijaf.20120203.03.html. (Accessed 11 March 2017).

[35] M. Lundy, M.V. Gottret, J. Ashby, Learning alliances: an approach for building multi-stakeholder innovation systems, in: *ILAC Brief 8*Rome: Bioversity, 2005.

[36] S. Ouma, This can ('t) be an asset class: the world of money management,"society", and the contested morality of farmland investments, Environ. Plann.: Econ. Space 52 (1) (2020) 66–87.

[37] A. Shimeles, A. Verdier-Chouchane, A. Boly, Conclusions: Enhancing the Resilience and Sustainability of the Agriculture Sector in Sub-saharan Africa. Building a Resilient and Sustainable Agriculture in Sub-saharan Africa, 2018, p. 285.

[38] L. Klerkx, M. Schut, C. Leeuwis, C. Kilelu, Advances in knowledge brokering in the agricultural sector: towards innovation system facilitation, IDS Bull. 43 (5) (2012) 53–60.

[39] L. Klerkx, A. Hall, C. Leeuwis, Strengthening agricultural innovation capacity: are innovation brokers the answer? Int. J. Agric. Resour. Govern. Ecol. 8 (5–6) (2009) 409–438.

[40] D.J. Spielman, F. Hartwich, K. Grebner, Public- private partnershIPs and developing country agriculture: evidence from the international agricultural research system, Publ. Adm. Dev. 30 (2010) 261–276.

[41] C. Latchem, Informal Learning and Non-formal Education for Development, 2014.

[42] C.O.L. in Action, Lifelong for Farmers, 17/2, Connection July, 2012, pp. 6–10.

[43] D. John, A. Krishna, *Using Technology to Expand Learning: Helping farmers Prosper*. Commonwealth Finance Ministers Reference Book, Henley Media Group, 2006. www.henleymediagroup.com.

[44] K. Balasubramanian, M. Ajit, A. Krishna, *Network for lifelong learning and rural poverty reduction in Asia: lessons and challenges.* Commonwealth finance Ministers Reference Book, Henley 12 (1) (2006) 9–12.

[45] S. Mishra, P.K. Misra, Open, Distance, and Digital Non-formal Education in Developing Countries, 2022.

[46] A. Hall, Public–private partnerships in an agricultural system of innovation: concepts and challenges, Int. J. Technol. Manag. Sustain. Dev. 5 (2006) 3–20.

[47] R. Kalibwani, M. Kakuru, A. Carr, M. Tenywa, Scaling smallholder farmer empowerment: lessons from the lifelong learning program in Uganda, Journal of Learning for Development 8 (2) (2021) 431–447.

[48] S. Nederlof, M. Wongtschowski, in: F. van der Lee (Ed.), Putting Heads Together: Agricultural Innovation Platforms in Practice, The Netherlands, KIT publishers, 2011.

[49] K. Asayehegn, G. Weldegebrial, D. Kaske, Effectiveness of development agents performances in agricultural technology dissemination: the case of Southern Nations Nationalities and Peoples Regional State (SNNPRS), Ethiopia, J. Agric. Ext. Rural Dev. 4 (17) (2012) 446–455.

[50] M. Challa, U. Tilahun, Determinants and impacts of modern agricultural technology adoption in west Wollega: the case of Gulliso district. Journal of Biology, Agriculture and Healthcare 4 (20) (2014) 63–77.

[51] A.A. Kinyangi, Factors Influencing the Adoption of Agricultural Technology Among Smallholder Farmers in Kakamega North Sub-county, Kenya, Doctoral dissertation, University of Nairobi, 2014.

[52] C. Rasanjali, P. Sivashankar, R.P. Mahaliyanaarachchi, Women participation in rural tourism: a case of ella, Sri Lanka, AGRARIS: Journal of Agribusiness and Rural Development Research 7 (2) (2021) 256–269.

[53] A.D. Kehinde, A.A. Ogundeji, The simultaneous impact of access to credit and cooperative services on cocoa productivity in South-western Nigeria, Agric. Food Secur. 11 (1) (2022) 11.

[54] G. Mgendi, S. Mao, F. Qiao, Is a training program sufficient to improve the smallholder farmers' productivity in Africa? Empirical evidence from a Chinese agricultural technology demonstration center in Tanzania, Sustainability 13 (3) (2021) 1527.

[55] Y. Nakano, T.W. Tsusaka, T. Aida, V.O. Pede, Is farmer-to-farmer extension effective? The impact of training on technology adoption and rice farming productivity in Tanzania, World Dev. 105 (2018) 336–351.

[56] G. Danso-Abbeam, D.S. Ehiakpor, R. Aidoo, Agricultural extension and its effects on farm productivity and income: insight from Northern Ghana, Agric. Food Secur. 7 (1) (2018) 1–10.

[57] J.M.N. Djomo, F. Sikod, The effects of human capital on agricultural productivity and farmer's income in Cameroon, Int. Bus. Res. 5 (4) (2012) 134.

[58] Y. Kijima, Y. Ito, K. Otsuka, Assessing the impact of training on lowland rice productivity in an African setting: evidence from Uganda, World Dev. 40 (8) (2012) 1610–1618.
[59] Y. Nakano, T.W. Tsusaka, T. Aida, V.O. Pede, The Impact of Training on Technology Adoption and Productivity of Rice Farming in Tanzania: Is Farmer-To-Farmer Extension Effective, JICA-RI working paper, 2015, p. 90.
[60] J. Ulimwengu, O. Badiane, Vocational training and agricultural productivity: evidence from rice production in Vietnam, J. Agric. Educ. Ext. 16 (4) (2010) 399–411.
[61] J.C. Aker, Dial "A" for agriculture: a review of information and communication technologies for agricultural extension in developing countries, Agricultural economics 42 (6) (2011) 631–647.
[62] Bint, S. Zaman, W. Farooq, S. Majeed, H. Shah, A. Majid, Assessment of agriculture service providers' training on water conservation technologies in Pothwar region, Pakistan J. Agric. Res. 29 (1) (2016).
[63] R. Llewellyn, D.J. Pannell, D. J, R. Wilkinson, P. Dolling, J. Ouzman, M. Ewing, Predicting farmer uptake of new agricultural practices : a tool for research , extension and policy, Agric. Syst. 156 (2017) 115–125.
[64] S. Ghosh, A. Kumar, T. Mohapatra, Impact assessment of the farmers' trainings on scaling up of water productivity in agriculture, Indian Research Journal of Extension Education 13 (1) (2013).
[65] B.N. Kalasariya, N.D. Bharad, M.K. Jadeja, Impact of training programme in terms of gain in knowledge for sustainable agriculture. Guj, Journal of Extension Education 26 (2) (2015) 154–157.
[66] H. Luo, L. Ji, B. Shi, H. Huang, N. Duan, T. Li, M. Zhou, Univl: A Unified Video and Language Pre-training Model for Multimodal Understanding and Generation, 2020 *arXiv preprint arXiv:2002.06353*.
[67] S.K. Seelan, S. Laguette, G.M. Casady, G.A. Seielstad, Remote sensing applications for precision agriculture: a learning community approach, Remote sensing of environment 88 (1–2) (2003) 157–169.
[68] S.D. Dercon, O.G. Daniel, H. John, W. Tassew, The impact of agricultural extension and roads on poverty and consumption growth in fifteen Ethiopian villages, Am. J. Agric. Econ. 91 (2009) 1007–1021.
[69] B. Gebremedhin, H. Dirk, T. Azage, Commercialization of Ethiopian agriculture: extension service from input supplier to knowledge broker and facilitator, Available online: http://cgspace.cgiar.org/handle/10568/564, 2006. (Accessed 23 November 2011).
[70] K.M. Wonde, A.S. Tsehay, S.E. Lemma, Determinants of training participation at farmers training centers in Northwest Ethiopia, International Journal of Training Research (2022) 1–26.
[71] M.G. Wordofa, M. Sassi, Impact of farmers' training centres on household income: evidence from propensity score matching in Eastern Ethiopia, Soc. Sci. 7 (1) (2017) 4.
[72] A.D. Kehinde, R. Adeyemo, Probit analysis of factors affecting improved technologies dis-adoption in cocoa-based farming systems of southwestern Nigeria, International Journal of Agricultural Economics 2 (2) (2017) 35–41.
[73] A. Ogunleye, A. Kehinde, A. Mishra, A. Ogundeji, Impacts of farmers' participation in social capital networks on climate change adaptation strategies adoption in Nigeria, Heliyon 7 (12) (2021), e08624.
[74] A. Kehinde, M. Kehinde, The impact of credit access and cooperative membership on food security of rural house-holds in south-western Nigeria, Journal of Agribusiness and Rural Development 57 (3) (2020) 255–268.
[75] W. Ma, H. Zheng, P. Yuan, Impacts of cooperative membership on banana yield and risk exposure: insights from China, J. Agric. Econ. 73 (2) (2022) 564–579.
[76] X.X. Zheng, J. Guo, F. Jia, S. Zhang, Cooperative game theory approach to develop an incentive mechanism for biopesticide adoption through farmer producer organizations, J. Environ. Manag. 319 (2022), 115696.
[77] A. Goldberger, Structural equation methods in social sciences, Econometrica 40 (6) (1972) 979–1001.
[78] A. Hayes, K. Preacher, Statistical Mediation Analysis with a multicategorical independent variable, Br. J. Math. Stat. Psychol. 67 (2014) 451–470.
[79] K. Imai, L. Keele, D. Tingley, A general approach to causal mediation analysis, Psychol. Methods 15 (4) (2010) 309–340.
[80] J. Angrist, G. Imbens, D. Rubin, Identification of causal effects using instrumental variables, J. Am. Stat. Assoc. 91 (1) (1996) 444–455.
[81] R. Baron, D. Kenny, The moderator-mediator variable distinction in social psychological research, Conceptual, Strategic and Statistical Considerations, Journal of personality and social Pscychology 51 (6) (1986) 1173–1182.
[82] J. Heckman, R. Pinto, Econometric mediation analyses, identifying the sources of treatment effects from experimentally estimated production technologies with unmeasured and mismeasured inputs, Econom. Rev. 34 (1) (2015) 6–31.
[83] R. Pinto, C. Dippel, R. Gold, S. Hebich, Mediation Analysis in IV Settings with a Single Instrument, 2019. UCLA working paper p. 40.
[84] R. Hicks, D. Tingley, Causal Mediation Analysis The Stata Journal 11 (4) (2011) 605–619.
[85] C. Dippel, A. Ferrara, S. Heblich, Causal mediation analysis in instrumental-variables regressions, STATA J. 20 (3) (2020) 613–626.
[86] F. Kleibergen, R. Paap, Generalized reduced rank tests using the singular value decomposition, J. Econom. 133 (1) (2006) 97–126.
[87] J. Stock, M. Yogo, Asymptotic distributions of instrumental variables statistics with many instruments, Identification and inference for econometric models: Essays in honor of Thomas Rothenberg 6 (2005) 109–120.
[88] Iacobucci, D., Mediation analysis and categorical variables: The final frontier. *Journal of Consumer Psychology* 22 (4) (2012) 582-594.Lacobucci G., CCGs ration care for obese and smokers with new wave of restrictions, PULSE (2012). (Accessed 7 March 2012).
[89] T.K. Adesina, F. Eforuoku, Determinants of participation in youth-in-agriculture programme in Ondo State, Nigeria, Journal of Agricultural Extension 21 (1) (2017) 80–94. https://www.ajol.info/index.php/jae/article/view/149326.
[90] A.D. Kehinde, A.A. Ogundeji, Distributive impacts of non-farm income on output and farm income of cassava farmers in Southwestern Nigeria, Scientific African 19 (2023), e01535.
[91] R. Adeyemo, A.D. Kehinde, Membership in association, gender and adoption of land-enhancing technologies among arable farmers in Ogun state, Nigeria, Agricultural Science & Technology 12 (2) (2020), 1313-8820.
[92] A. Kehinde, Agricultural cooperatives and improved technologies adoption among smallholder farmers in cocoa-based farming systems of southwestern Nigeria, Int. J. Agric. Manag. Dev. 11 (4) (2021) 467–483.
[93] R. Adeyemo, A.D. Kehinde, L.O. Oyenpemi, Assessing resource use efficiency and investment in cocoa enterprise: a case of Osun State, Nigeria, Agricultura 113 (2020) 260–269.
[94] T.B. Alao, A.S. Bamire, A.D. Kehinde, Gender analysis of agricultural financing in cocoa-based farming system in Oyo and Osun States of South Western Nigeria, Ghana J. Agric. Sci. 55 (1) (2020) 34–42.
[95] D.P. Popoola, Divergent cooperative memberships. Exploring the determinants. A case study of poultry farming households in southwest Nigeria, Journal of Agriculture and Sustainability 13 (2020).
[96] A. Higuchi, Impact of a marketing cooperative on cocoa producers and intermediaries: the case of the acopagro cooperative in Peru, J. Rural Cooperat. 42 (886–2016-64710) (2014) 80–97.
[97] N.A.A. Etim, G.E. Edet, Efficiency of resource utilization in dry season waterleaf Talinum triangulare Jacq. wild production by women in southern Nigeria, Asian journal of Agricultural Extension, Economics and sociology 3 (2) (2014) 138–146.
[98] E. Martey, P.M. Etwire, A.N. Wiredu, W. Dogbe, Factors influencing willingness to participate in multi-stakeholder platform by smallholder farmers in Northern Ghana: implication for research and development, Agricultural and Food Economics 2 (1) (2014) 1–15.
[99] O.A. Asemokhai, J. Akangbe, C.O. Asemokhai, A. Eniayekan, S. Etta-Oyong, Assessment of farmers' participation in agricultural cooperative society in Kogi state, Nigeria, International Journal for Research Trends and Innovation 7 (2) (2022) 136–144.
[100] J.O. Ayinde, B.E. Olarewaju, D.L. Aribifo, Perception of youths on government agricultural development programmes in Osun State, Nigeria, Scientific Papers: Management, Economic Engineering in Agriculture & Rural Development 16 (3) (2016).
[101] Y.L. Idrisa, B.O. Ogunbameru, M.C. Madukwe, Logit and Tobit analyses of the determinants of likelihood of adoption and extent of adoption of improved soybean seed in Borno State, Nigeria, Greener Journal of Agricultural Sciences 2 (2) (2012) 37–45.

[102] P.C. Obasi, G.I. Okparadim, A. Henri-Ukoha, Determinants of net returns to agro forestry in the humid RainForest belt of Nigeria, European Journal of Agriculture and Forestry Research 2 (1) (2014) 18–30.
[103] K.K.S. Nxumalo, O.I. Oladele, Factors affecting farmers' participation in agricultural programme in Zululand district, Kwazulu Natal Province, South Africa, J. Soc. Sci. 34 (1) (2013) 83–88.
[104] A. Nahayo, M.O. Omondi, X.H. Zhang, L.Q. Li, G.X. Pan, S. Joseph, Factors influencing farmers' participation in crop intensification program in Rwanda, J. Integr. Agric. 16 (6) (2017) 1406–1416.
[105] A. Nahayo, M.O. Omondi, X.H. Zhang, L.Q. Li, G.X. Pan, S. Joseph, Factors influencing farmers' participation in crop intensification program in Rwanda, J. Integr. Agric. 16 (6) (2017) 1406–1416.
[106] K.K.S. Nxumalo, O.I. Oladele, Factors affecting farmers' participation in agricultural programme in zululand district, kwazulu natal province, South Africa, J. Soc. Sci. 34 (1) (2017) 83–88.
[107] A.R.S. Bello, Factors effecting the respondents participation in farmers field schools in khartoum state, Sudan, Advances in Social Sciences Research Journal 7 (4) (2020) 62–70.
[108] K. Davis, E. Nkonya, D.A. Kato, M. Mekonnen, R.M. Odendo, J. Nkuba, Impact of Farmer Field Schools on Agricultural Productivity and Poverty in Uganda, 2010. IFPRI Discussion Paper 00992 June 2010.
[109] A. Ayanwuyi, O.A. Akinboye, O.A. Olaniyi, Youth participation in rural development projects in surulere local government area of Oyo State, Nigeria, Soc. Sci. 2 (3) (2013) 312–317.
[110] J. Hao, J. Bijman, C. Gardebroek, N. Heerink, W. Heijman, X. Huo, Cooperative membership and farmers' choice of marketing channels–Evidence from apple farmers in Shaanxi and Shandong Provinces, China, Food Pol. 74 (2018) 53–64, https://doi.org/10.1016/j.foodpol.2017.11.004.
[111] S.D.P. Sudarshanie, *Factors Affecting on Youth Participation and Satisfaction in Occupation Related to Agriculture* (Doctoral Dissertation), 2015.
[112] O.M. Adesope, E.C. Matthews-Njoku, N.S. Oguzor, V.C. Ugwuja, Effect of Socio-Economic Characteristics of Farmers on Their Adoption of Organic Farming Practices, Crop Production Technologies, 2012, pp. 210–220.
[113] G. Onuwa, S. Folorunsho, Determinants of tomato farmers participation in agricultural services and training centre (ASTC) activities, Turkish Journal of Agriculture-Food Science and Technology 10 (8) (2022) 1369–1376.
[114] E.M. Panti, G.P. Gempes, The mediating effect of risk management strategies on the relationship between attitude constructs and sustainability of banana production in Southern Philippines, International Journal of Business and Administrative Studies 4 (2) (2018) 68.
[115] F.M. Feinberg, Mediation analysis and categorical variables: some further frontiers, J. Consum. Psychol. 22 (4) (2012) 595–598.
[116] D.P. MacKinnon, M.G. Cox, Commentary on "Mediation analysis and categorical variables: the final frontier" by Dawn Iacobucci, J. Consum. Psychol. 22 (4) (2012) 600–602.
[117] M.G. Wordofa, M. Sassi, Smallholder farmers' participation in agricultural training and demonstration in Ethiopia: implications for inclusive targeting by agricultural extension services, International Journal of Agricultural Science, Research and Technology in Extension and Education Systems (IJASRT in EES) 8 (3) (2018) 139–146.