Essays on Climate-Smart Agriculture (CSA) Technologies, Youth Involvement in Agricultural Activities, and Agricultural Finance

A thesis

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Abstract

The thesis presents four essays addressing key issues in smallholder agriculture in Tanzania, such as CSA technologies, youth involvement in farming, and agricultural finance. The thesis examines the effects of climate-smart agriculture (CSA) adoption on crop productivity and income. The thesis addresses the impact of climate change to enhance farm performance and improve farmers' resilience. Also, the thesis analyzes youth engagement in agriculture. Under this theme, the thesis seeks to understand how we can attract and keep youths in the agricultural sector as a response to alarming youth unemployment. Further, the thesis examines agricultural finance constraints and their impacts on farm performance. Access to agricultural finance by farmers is ideal for poor farm resource farmers to improve farm input usage and resilience.

Chapter 1 consists of the introductory part. Chapter 2 investigates the impacts of CSA on crop productivity and income using nationally representative data that sampled 1862 smallholder household farmers who cultivate less than 2 hectares. The chapter reports that smallholder farmers who practice CSA augment crop productivity per acre and income more than non-adopters. Interestingly, non-adopters, had they adopted, would have remarkably gained in both. The results survived robust checks and remained consistent. We used the endogenous switching regression (ESR) model, instrument variables, and other control variables to address the endogeneity and selection bias issues. The propensity score matching (PSM) is adopted for comparison and for a consistency check of the results. At least the results are consistent in both models. The implication of the findings is that plausible programs, promotions, campaigns, or policy support initiatives for scaling up CSA adoption have a significant contribution to food security and poverty reduction through increased crop productivity and income augmentation.

Chapter 3 contains two research papers. The first paper investigates youth involvement in agricultural activities, using a sample of 6419 Tanzanian youths aged 15-35 years old. The paper highlights the critical problems and challenges faced by youth in the agricultural sector. Further, the paper elucidates the crucial drivers of youth's full involvement in agriculture. The statistically significant drivers include access to and usage of farm machines (e.g., tractors), irrigation facilities, land ownership, presence of agro-product processing, profits, access to agricultural credit, youth membership in the farmers' cooperatives and organizations, access to and use of extension services, use of information source channels to access agricultural information, and distance to the nearest market. At the same time, off-farm income, general education, and age reduce the propensity of youth's involvement in agriculture. A series of robust checks were performed to ensure that the assumptions of the ordered logit model are met to ensure unbiased and consistent results. The second paper examines the impact of youths' intensive participation in agriculture on farm performance. We used nationally representative cross-sectional data of 3399 small youth farmers in Tanzania. We employed a doubly robust IPWRA estimator, and we compared these empirical results with the results from ESR and PSM models. The results remain statistically and quantitatively consistent in all models: that youth intensive involvement in agriculture significantly impacts maize yields, net returns, and returns on investment (ROI). Overall, both papers propose policy actions, academic interventions, and parental interventions to promote and retain many youths in agriculture.

Finally, chapter 4 contains one paper that used a sample of 1042 smallholder farmers. The paper examines the significant obstacles to agricultural financing that both the demand and supply sides of agricultural credit encounter. Further, the paper demonstrates the impact of agricultural finance on farm performance for credit-constrained smallholder farmers. We applied the ESR model to address the endogeneity problem and selection bias. Furthermore, PSM was used to compare the results of the ESR model. The results in both models are consistent that credit access augments smallholder farmers' crop productivity. Interestingly, farmers without credit counterfactual would increase their crop production if they were assumed to be credit unconstrained. The findings carry important policy implications in favour of smallholder farmers' credit access.

Key Words: agricultural finance, climate-smart agriculture, ESR, impact analysis, IPWRA, PSM, smallholder farmers, Tanzania, youth involvement.

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Declaration

I, Yohane Kitwima Magembe, declare that the content of this thesis is my original work at the University of Waikato in New Zealand. I endorse that, excluding where clear reference is made to the input of others and where past works mentioned are duly accredited, the work in this thesis is originally written by me. The thesis has not been submitted before, in whole or in part, to succeed in any academic reward anywhere else.

Thesis-related research outcomes

PAPERS ACCEPTED FOR PUBLICATION

1. Advancing Agriculture in Tanzania Through Climate-Smart Technologies

2. Sustainable Development Goals and Agricultural Finance

PAPERS UNDER DIFFERENT REVIEW STAGES

1. Drivers of Youth Intensity of Participation in Agriculture: Insights from Tanzania.

2. Youth Higher Intensity, Higher Gains? Empirical Evidence from Crop Farming in Tanzania

CONFERENCE/ PUBLICATION PAPERS

1. Impact of Conservation Intensity Adoption on Maize Production Among Small-Scale Farmers in Tanzania: A Doubly Robust Analysis

2. Cultural Diversity, Gender Gap, and Financial Literacy in Tanzania

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List of Abriviations and Acronyms

AfDB	African Development Bank
WUR	Wageningen University in Germany, Research Centre
AGRA	Alliance for a Green Revolution in Africa
ARC	Academic, Research, and Consultancy
ASDPII	Agricultural Sector Development Program Phase II
ATE	Average Treatment Effect
ATENT	Average Treatment Effect on not Treated
ATET	Average Treatment Effect on the Treated
AU	African Union
BBT-YIA	Building a Better Tomorrow – Youth Initiative for Agribusiness
CAADP	Comprehensive African Agricultural Development Programme
CI	Confidence Interval
CSA	Climate-Smart Agriculture
EAs	Enumerated Areas
ESR	Endogenous Switching Regression
FAO	Food and Agriculture Organization
FIML	Full Information Maximum Likelihood
FOs	Farmers' Organizations
GDP	Gross Domestic Product
GHG	Green House Gas
HR	Human Resource
ICT	Information Communication Technology
IFAD	International Fund for Agricultural Development
IPW	Inverse Probability Weight
IPWRA	Inverse Probability Weight Regression Adjustment
LR	Likelihood Ratio
LTV	Long-Term Vision
NBS	National Bureau of Statistics
NGOs	Non-governmental organizations
NSCA	National Sample Census of Agriculture
NSYIA	National strategy for youth involvement in agriculture
OCGS	Office of the Chief Government Statistician
PFA	Planning, Finance, and Administration
PhD	Doctor of Philosophy
PPS	Probability Proportionate to Size
PSM	Propensity Score Matching
PSUs	Primary Sampling Units

RA	Regression Adjustment
SCGS	Smallholder Credit Guarantee Scheme
SDGs	Sustainable Development Goals
SE	Standard Errors
SLT	Social Learning Theory
SMEs	Small and Medium Enterprise
SSA	Sub-Saharan Africa
SUA	Sokoine University of Agriculture
TADB	Tanzania Agricultural Development Bank
TET	Treatment Effect on Treaties
TEU	Treatment effect on the untreated
TNCFI	Tanzania National Council for Financial Inclusion
TV	Television
TZS	Tanzanian Shillings
UDOM	University of Dodoma
UN	United Nations
URT	United Republic of Tanzania
USD	United States Dollar
WB	World Bank

Chapter 1

Introduction

1.1. Background of the thesis

The thesis consists of three (3) related themes in the transformation of small farmer agriculture in Tanzania. The themes include climate-smart agriculture (CSA) technologies, youth involvement in agriculture, and agricultural finance. The themes play simultaneous roles in improving agricultural practices and in the attainment of sustainable development goals (SDGs). They enhance agricultural transformation by improving farming performance. CSA enhances crop productivity, mitigation, and increasing agricultural resilience when facing the implications of climate change (Bhatnagar et al., 2024). Youth involvement in agriculture ensures labour supply and boosts crop production (Geza et al., 2022), while agricultural finance improves resilience and farm input access and usage for constrained farmers (Agbodji & Johnson, 2019; Amadu et al., 2020; Assouto et al., 2023; Baloyii et al., 2023; Boansi et al., 2024; Tripathi, 2017).

The themes are presented in four (4) papers that address problems such as climate change impacts, youth unemployment, and agricultural finance constraints. Addressing them will enhance agricultural performance and foster attainment of some SDGs, such as 1st no poverty, 2nd zero hunger, 8th decent job creation for all and economic growth, and 13th mitigating climate change impacts (UN, 2015).

Further, the themes are the mega agenda for Africa's agricultural transformation as articulated in the Malabo Montpellier Panel in 2018 and 2019, among other agendas (Daum et al., 2022). However, other topics that call for the attention of the stakeholders for sustainable agricultural performance include mechanization, fertilizer and pesticide use, livestock development, land reforms, biodiversity conservation, and digitalization of agriculture (ibid.). Further, mechanization, fertilizers, and pesticide use require resources such as agricultural finance, which is discussed in this thesis.

Climate change has received formal attention in recent decades due to the recognition of its hazards and impacts. The topic has continuously attracted stakeholders in choosing and designing the most promising interventions, such as policies or programs for resilience (Daum et al., 2022). The ongoing debate is based on the trade-off and synergy between maximizing crop production, social outcomes, and protecting the environment (Jones et al., 2023). Overuse of chemicals and expanding cultivation of land harm the environment and eventually lead to a decline in agricultural productivity (Feng et al., 2023). Stakeholders call for climate-friendly agricultural practices (FAO, 2013).

Further, expansion of settlements and human activities such as rapid industrialization harm the ozone layer, which leads to global warming due to the emission of greenhouse gas (GHG) (Winthrop et al., 2018). As a result, the planet is at risk of harming lives and the environment. The incidence of climate change impacts varies according to the place location, economic stability, and preparedness to face adverse conditions (Akter et al., 2022; Khatri-Chhetri et al., 2017).

In countries in Sub-Saharan Africa (SSA), the farmers are known to be resource-poor with the use of basic equipment in farming (Ngaiwi et al., 2023). They mark high risk and vulnerability to climate change variations (Daum et al., 2022). A large share of the population engages in small-scale agriculture that is managed by family and smallholder farming (Acclassato et al., 2021). There are 570 million smallholder farms worldwide that cultivate less than 4.9 acres or 2 hectares[1] (Roop et al., 2023). Small farmers increasingly occupy a large share of the farming population and produce 69% of food (FAO, 2015). Smallholder farmers mainly depend on rain-fed small-scale agriculture for their livelihood, although it is extremely vulnerable to climate change and variability (Nyasimi et al., 2017).

Severe events such as prolonged droughts, floods, diseases, and pests affect farming in the adverse climate change (Winthrop et al., 2018). They threaten agricultural activities, livelihood, and agricultural economy, especially in the resource-poor developing countries (Huang et al., 2011). The small farmers' well-being and the rural economy are affected given that crop markets are interrupted by climate change, which harms the food supply (Hellin & Fisher, 2018).

[1] One acre is estimated to be 0.4 ha (Nikam et al., 2022).

Consequently, poverty, hunger, food insecurity, low economic growth, environmental degradation, and unemployment are predominant (FAO, 2017).

Policymakers claim that addressing climate-induced shocks threatening agriculture is a top priority since climate is crucial for crop productivity (Akter et al., 2022). Measures have been put in place to reduce the effects of climate change on farming. The measures improve farmers' adaptive ability, resilience, and efficient utilization of scarce resources in agricultural activities (Bierbaum & Zoellick, 2009; Islam & Nursey-bray, 2017). The international bodies reinforced some adaptive plans, strategies, laws, and policies (UNEP, 2022). The measures may range from policies, sectoral, international agencies, NGOs, and individuals (Bongole et al., 2022).

To this end, CSA is the most suitable approach (Bierbaum & Zoellick, 2009; FAO, 2013; Saj et al., 2017; URT, 2015). It ensures a sustainable increase in crop productivity, builds resilience in food systems, and adapts to adverse climatic conditions (URT, 2015)**.** The ongoing promotion of CSA-practices projects and programs in farming has not reached the desirable expectations (Mugabe, 2020). The adoption of CSA practices is still voluntary, making CSA technologies not broadly or partially used in the different parts of the country (Ngaiwi et al., 2023) because of limited capacity, overdependence on donors' fund programs, and policy support (Bongole et al., 2022; Mugabe, 2020).

At the national level, challenges emanate from readiness mechanisms, services and infrastructures, and coordination mechanisms (Newell et al., 2019) that a particular country fails to align with the global SDGs goal imagination, such as the attainment of the 13^{th} goal of combating climate change and its impact (UN, 2015).

At the farm level, availability and access to resources such as financial capital, land, and labour-intensive bottleneck CSA adoption (Nyasimi et al., 2017). Further, uncertain gains accrued after adopting CSA technologies (Akter et al., 2022), skills and knowledge about CSA technology, ability to cope with challenges that might arise during or after using the practices (Ogada et al., 2021), compatibility with local social and cultural practices (Sanga et al., 2013; Waithaka et al., 2007), weak information flow and linkages between farmers and extension officers regarding CSA usage, and risk management (Nyasimi et al., 2017).

The current strand of research about CSA technologies elucidate that seed access and consumers' acceptability of seed varieties, yield potential, extension service, farm size, education, and age (Mittal & Mehar, 2015), household size, plot ownership, and institutional characteristics (Bongole et al., 2022), and the use of ICT such as mobile phones on improved technologies (Khatri-Chhetri et al., 2016; Mittal & Hariharan, 2018; Nyasimi et al., 2017) are important determinants of CSA-practices usage.

At least the extant literature indicates rare investigations have been done on crop productivity and environmental consequences of CSA adoption (Feng et al., 2023). The impact on household crop productivity and income is not fully documented. Also, climate change impact is contextual, requiring location-specific investigation. This thesis adds to the extant strands of research on the impact of CSA adoption on crop productivity and income for smallholder farmers. We examine the determinants and impact of CSA on crop productivity and income using cross-sectional data from Tanzania.

Two essays are presented under the youth involvement in agriculture theme. The first essay focuses on problems and challenges facing youth in the sector and the drivers of youth involvement in the agricultural activities. The second essay under this theme focuses on the intensification of youth involvement and their impact on farming performance in agriculture. The two essays aim to address the alarming youth unemployment threat by attracting youth and keeping them in the agricultural sector. The extant literature on youth involvement in agriculture presents low involvement following the negative perceptions and youth negligence on agriculture (Daum et al., 2022). Youth negligence in agricultural activities has resulted in persistent poverty and food insecurity in many developing countries (URT, 2022a).

To this end, many governments in developing economies face a critical challenge of youth unemployment (Miriti, 2020) and underdevelopment for hundreds of millions of young people graduating from schools, tertiary institutions, and universities due to low buy-in in agriculture (The Alliance for a Green Revolution in Africa (AGRA), 2019).

Youth intensity participation in agriculture is a function of youth backgrounds, institutional, and socio-economic statuses of a particular society, which nurture perceptions, attitudes, and intentions to participate in the sector (Ninson & Brobbey, 2023). Youth can be encouraged or discouraged only if the environment nurtures positivity or negativity towards agricultural activities (Henning et al., 2022).

The growing research strand about youth participation in agriculture presents two major antagonistic views. The first is a positive perception and intention to participate in agriculture (Maritim, 2020; Magagula & Tsvakirai, 2020), and the second is a negative perception of negligence to engage in agriculture (Heifer International, 2021; Sumberg et al., 2017).

Both perceptions are nurtured by problems and challenges that face youth in the agricultural sector and experiences from leaders and elders in a particular area (Shayo, 2020). The problems and challenges youth face in the sector make agriculture less attractive and not a preferred career. Subsequently, low youth engagement in agricultural activities (IFAD, 2019).

Despite interventions by stakeholders to attract and keep youth in the sector, their effectiveness remains unclear (URT, 2022a). The effects and outreach of the initiatives are localized, many training about horticulture, and concentrating in major producing zones, while other youths are left unfacilitated. The initiatives have not yet produced the anticipated flow of youth into the agricultural sector and have remained a challenge.

Attracting youth is one issue, and retaining them remains a global challenge (Mukembo et al., 2014). The low youth response to initiatives alerts us that there are possible drivers affecting youth involvement in agricultural activities.

To fill this gap, the current thesis investigates the problems and challenges that nurture youth negative perceptions and neglect of agriculture and the drivers of youth intensity of participation in agriculture in Tanzania. Further, for informed policy actions, the thesis presents the impact of youth intensification involvement in agriculture on farming performance.

Lastly, the thesis presents an agricultural finance theme in one essay, which investigates agricultural financing for smallholder farmers and its impact on crop farming. Developing countries face inadequate agricultural finances, causing considerable credit access constraints for smallholder household farmers.

Furthermore, climate change impact increases the average cost of keeping one acre due to unreliable precipitation, floods, drought, storms and landslides, soil quality decline, diseases, and pests as the impact of climate change puts lives and the environment at risk (Arce & Arias, 2015; Shemsanga et al., 2010), which increases the necessity of agricultural finance.

Agricultural finance not only improves farm's inputs usage but also increases the resilience to climate-induced shocks of resource-poor farmers (Amadu et al., 2020). It is crucial to improve investment in the sector where farmers will be able to have all the necessary agricultural inputs for farming.

Credit constraint for smallholder agriculture in developing countries is documented (Acclassato et al., 2021; Agbodji & Johnson, 2019; Assouto et al., 2023; Bergen et al., 2019; Y. Hu et al., 2021; Ji-kun & Yang-jie, 2014; Mthi et al., 2021; Tripathi, 2017).

However, empirical evidence on the effects of credit access on crop productivity is scant and is missing in the Tanzanian context. It is unknown whether agricultural finance augments crop productivity for Tanzanian smallholder farm households.

In this context, the thesis investigates the impact of credit access on crop productivity in Tanzania, one of the developing countries with weak agricultural finance and pronounced credit constraints.

Credit access is one of the mega agendas in transforming agriculture (Daum et al., 2022). It unlocks the opportunity to access necessary farm inputs and market networks, farm management, and resilience in adverse climatic conditions (Abdulai, 2016; Akter et al., 2022; Amadu, McNamara, et al., 2020; Noltze et al., 2013; URT, 2016b).

Without financing agriculture, even transforming it and be able to meet some of the global SDGs come into reality becomes a far dream (Acclassato et al., 2021). The farmers, especially smallholder farmers, who occupy a large segment of famers and produce over 69% of food are resource-poor (Acclassato et al., 2021; Agbodji & Johnson, 2019; Assouto et al., 2023; FAO, 2015; Ngaiwi et al., 2023).

The novelty of this thesis is that it discusses new evidence of the impacts of CSA technologies, youth involvement intensification, and agricultural finance on farm productivity and income augmentation of smallholder farmers in Tanzania. The thesis investigates contemporary problems and challenges faced by youth in the sector. Further, the thesis examines the drivers that influence youth intensity of involvement in agriculture using data from the National Sample Census of Agriculture (NSCA) 2020 from Tanzania. We present how we can attract and retain youth in agricultural activities through the exogenous factors that nurture youth intensity of engagement in agriculture.

Further, the thesis examines the impact of agricultural finance on crop productivity. In countries with less effective agricultural credit schemes, the association between farm credit constraints with low crop productivity and food insecurity is even more pronounced. Using data samples from the ‘‘Integrated Project to Increase Agriculture Productivity in the Breadbasket Area of Southern Highlands” for Mbeya and Songwe regions in Tanzania, the thesis investigates how agricultural finance augments crop productivity among credit-constrained smallholder farmers. This study contributes to the existing literature about the impact of agricultural finance on crop productivity among farmers cultivating less than 2 hectares. The investigation is scant in the extant literature, and it is still missing in Tanzania.

The following sections (1.2 to 1.4) provide an overview of the three themes that are included in this thesis.

1.2. Climate-smart agriculture (CSA) technologies

The first essay focuses on the impact of CSA adoption on crop productivity and income augmentation. It examines the impact of CSA adoption on crop productivity and income of smallholder farmers using data from NSCA in Tanzania.

CSA as a concept was first used by the World Bank (WB) as a policy option in financing carbon reduction, economic development, and decreased vulnerability since 2009 (Bierbaum & Zoellick, 2009). The application of CSA in agricultural practices is scaling up over time (Taylor, 2017). CSA is an integrated strategy that entails three goals. The goals include promoting agricultural productivity, adapting to climate change risks and stress, and reducing greenhouse gas (GHG) emissions from agricultural practices (FAO, 2013; Saj et al., 2017).

Anthropogenic activities such as agriculture and land use change are contributing to the emission of GHG, which fuels climate change impacts (Winthrop et al., 2018). The agricultural sector is contributing to GHG emissions by 10% to 20% (Allen et al., 2020). Sub-Saharan Africa (SSA) contributes only 7% of the globe's GHG emissions from agriculture. It is the least compared to other regions, yet it has the highest vulnerability to climate change impacts. Further, the GHG emissions are projected to reach 1.7 gigatons within 2050 (Ntinyari & Gweyi-onyango, 2021).

Following the mechanization of agriculture and land-use change, it is expected that GHG emissions will rise in the future if no measures are taken (Winthrop et al., 2018). GHG emissions lead to global warming, which triggers climate change hazards and impacts (Shakoor et al., 2021). Climate change stress is already observed, coupled with a global population increase estimated to hit 9 billion by 2050 (Williams et al., 2016). Currently, 821 million individuals are suffering from food insecurity, of which 236 million people are from SSA (FAO, 2019). Africa will have a large share of this population who will be suffering from food insecurity (FAO, 2017). To curb the situation, deliberate initiatives are required at global, regional, country, and local levels.

As a response at the global level, scientific and civil societies are debating the best strategies to manage population increase, agricultural production, adaptation to climate change impacts, and mitigation of GHG emissions (Saj et al., 2017; Jagustovi et al., 2021) to end poverty and hunger, combat climate change impacts, and ensure inclusive economic growth for all (UN, 2015). FAO advocates for the implementation of CSA technologies in agricultural practices. CSA improves resilience to the challenges resulting from climate change shocks, population increases, and food insecurity (FAO, 2010; FAO, 2013). The adoption of CSA technologies has appeared to be a strategic solution that enhances sustainable agriculture and the environment (Bhatnagar et al., 2024; Khatri-Chhetri et al., 2016; URT, 2015).

In Africa, leaders have in place a comprehensive African Agricultural Development Program (CAADP) and 2063 agenda after some decades of agricultural sector neglect (Daum et al., 2022; Ogada et al., 2021) that aims at ensuring food security and economic development. However, many African countries are characterized by limited resources to combat climate change impacts, where food insecurity, poverty, and stagnant economic growth are increasingly dominant. Those who entirely depend on agriculture suffer the most (Berger et al., 2017). They sell their assets to face climate change impacts and remain in absolute poverty (Dercon & Christiaensen, 2011). Hence, the adoption of CSA technologies is an indelible option to improve crop productivity for food security and income generation, which increases resilience to the threatening climate change.

In Tanzania, there is political will from the government to create an enabling environment to promote CSA practice through policies, plans, strategies, and learning opportunities that aim at transforming agricultural practices (URT, 2016b). For instance, the National Agriculture Policy of 2013 (URT, 2013), the National Development Vision 2050 and the long-term vision (LTV) for a long-term, integrated, low-emission, climate-resilient future in Tanzania to have net-zero emissions by 2050 (URT, 2025).

Despite the implementation of the state and sector-led efforts, Tanzania is increasingly witnessing the impacts and severe events of climate change, such as rising sea levels, high temperatures, floods, and prolonged drought, coupled with population increase at the rate of 3% and urbanization at 30% (Craparo et al., 2015; Winthrop et al., 2018). They threaten food security, poverty reduction efforts, and economic development plans.

CSA as a concept and practice in Tanzania is increasingly gaining attention following the climatic shocks witnessed in the environment and livelihood. CSA is well-coordinated at national and sector levels, but at the lower level, where small farmers are found, it is not well implemented (Winthrop et al., 2018) and its adoption is still voluntary. Also, the implementation of CSA is still location-dependent, localized solutions in policies, limited extension services, and development interventions are a few setbacks of the CSA integration scale-up in agriculture (Autio et al., 2021; Kimaro et al., 2015; URT, 2013). However, the farm-level CSA technologies adoption is viable (Berger et al., 2017) because it is a point where the incidence of climate change is felt.

CSA technologies refer to agricultural operations implemented on a piece of land (plots) owned, leased, and used by a certain family, normally smallholders regardless of gender, economics, or other statuses (Scherr et al., 2012). The most practiced CSA technologies include water, knowledge and skills, weather, energy, nutrients, and carbon smarts (Bongole et al., 2022; Craparo et al., 2015; Kurgat et al., 2020; Mwongera et al., 2017; Nyasimi et al., 2017; Ogada et al., 2021; Rowhani et al., 2011; Shemsanga et al., 2010; Teklewold et al., 2020).

The growing strand of research about CSA technologies affirms that farmers who adopt them increase their crop productivity and protect their environment, unlike their counterparts who never adopt them (Khatri-Chhetri et al., 2016). However, such knowledge is unclear in the extant literature about Tanzania. Further, studies about CSA technologies are limited in Tanzania (Bongole et al., 2020), especially on whether adopting CSA improves crop productivity and income.

Awareness and practices of CSA at the farm level help farmers save lives, assets, the environment, and natural resources (Berger et al., 2017). Low practices of CSA technologies at the farm level jeopardize the goal of zero hunger in Tanzania by 2030 (URT, 2016b). CSA practices at the farm level are crucial because many people engage in agriculture, and it has potential for farmers' income generation and poverty reduction (Mwongera et al., 2017). Despite the potential of CSA adoption by smallholder farmers, it is unknown if farmers adopting CSA can increase farm productivity and augment income.

The thesis examines the impact of farm-level adoption of CSA on farm production and income by smallholder farmers. CSA technologies adoption is relevant as they reduce costs to adapt to climate change impacts. The costs of adaptation to adverse climate conditions are too high. For instance, for the agricultural sector only, the costs are estimated at USD 203 million and expected to consume about 2% of GDP by 2030 (Arce & Arias, 2015). Further, the findings in this thesis are relevant to poverty reduction and reliable food security through improved crop production and income.

1.3. Youth involvement in agricultural activities

The second essay of this thesis presents youth involvement in agricultural activities. Youth engagement in agriculture remains a major challenge, both at the global and national levels, generating a pool of unemployed youth. Africa's population comprises youth under the average age of 25 years (URT, 2022a). African youth account for 60% of the population, which is equivalent to 1.2 billion youth (FAO, 2018). African youth will increase by 40% by 2030 (AfDB, 2016). Youth are predicted to continue to grow in number in the future (Sakketa & Gerber, 2017).

The agricultural sector has potential for youth employment (African Union, 2006) because it is able to absorb large populations, both skilled and unskilled (Akrong & Hundie, 2022). Youth involvement in agriculture transforms the performance of the sector (Betcherman, 2018; Chakrabarti, 2018; FAO, 2018). Youth are mentally and physically fit, energetic, dynamic, active, educated, and quick in novel technologies acquisition compared with elders (Maiga, 2016; Magagula & Tsvakirai, 2019). Having many youths in a population is a comparative advantage for African countries. They can be a good source of cheap labour supply and potential for future markets.

Furthermore, many youths ensure the inheritance of agriculture from elders. They can improve crop availability, improve the good image of agriculture, and increase job creation through involvement in the agricultural value chains. Enhancing youth full participation in agriculture can control youth urban influx and the likely problems (Akrong & Hundie, 2022).

Youth involvement in agriculture fosters the attainment of the SDGs, such as inclusive economic growth, employment, and decent job creation for all (UN, 2015). The sector is striking and more profitable in a wide range of value chains (Akrong & Hundie, 2022). The agricultural sector is the key not only to youths' employment but also to Africa's economies that depend on the sector for livelihood and economic growth.

Promotion of youth engagement in the agricultural sector can be an opportunity to improve food security by increasing crop production and poverty reduction through income generation (Kwaku et al., 2017). It can contribute to the attainment of SDGs such as ending hunger and poverty (Osabohien et al., 2021).

Despite the prosperities embedded in youth involvement in agriculture, the promotion efforts to attract youth to the sector in the African continent and elsewhere have not won youth interests. Many countries still experience low youth buy-in in the sector (Magagula & Tsvakirai, 2019). They consider agriculture to be less striking, labour exhaustive, and low self-esteem (IFAD, 2019).

Negligence towards agriculture manifests more in town centers due to rural-urban migration parallel with population increase (Akrong & Hundie, 2022). There are limited job creation opportunities in other African sectors to absorb the increase of the unemployed population, which is partly explained by the mismatch between jobs and skills required in the labour market (Morsy & Mukasa, 2019).

Agriculture remains the only sector rich in terms of immediate opportunities for all age cohorts, skilled and unskilled. Only in the agricultural sector youth can immediately generate enough income through engagement in it (Ninson & Brobbey, 2023; The Alliance for a Green Revolution in Africa (AGRA), 2019).

To restrain the impact of youth unemployment in African countries, practitioners and policymakers are of the view that promotion and motivation of youth engagement in agriculture is crucial (Filmer & Fox, 2014). Also, promotion of awareness of the economic prospects available in the agricultural value chains (Magagula & Tsvakirai, 2019) can intrinsically motivate youth’s involvement in agriculture.

Tanzania is one of the Southern Global countries experiencing youths’ negligence in the agricultural sector while the economies in these countries depend on agricultural performance. In the Tanzanian context, youth is a person aged 15 to 35 years (Msangi et al., 2024; URT, 2007; Verick, 2009). Tanzania has the youngest population globally, with an average age of 18 years old (URT, 2022a). They are 34.7% of the entire population, according to the 2022 Census (URT, 2022b). Youths account for 65% of the labour force, while most of them are unemployed. The number of unemployed youth hits 11.5% with an increase rate of 3.49% per year in Tanzania (URT, 2022b).

Tanzania experiences youth dynamics participation in agriculture just like in other countries (Kafle et al., 2019). Youth abandoning agriculture makes the sector remain weak over time. Youth disinterest in agriculture fuels national food insecurity, persistence of unemployment, and poverty (Chakrabarti, 2018; Lindsjö et al., 2020; URT, 2022a).

In Tanzania, youth engagement in agriculture has been a core focus area of key policies such as the National Youth Development Policy 2007 (URT, 2007), the National Agriculture Policy 2013 (URT, 2013), the National Strategy for Youth Involvement in Agriculture program 2016 (URT, 2016a), the Agricultural Sector Development Program Phase II (ASDP II) 2017 (URT, 2017), and the Building A Better Tomorrow: Youth Initiative For Agribusiness (BBT-YIA) 2022-2030 program (URT, 2022a).

They offer technical, financial, and non-financial support to youth participation in agriculture. Tanzania collaborates with other development partners, private sectors, NGOs, and individuals to support youth engagement in the sector (URT, 2022a). Most of these efforts are state-led and they depend on donor’ funds, which limit their effectiveness to youths at the grassroots level (Magagula & Tsvakirai, 2020).

Academicians have contributed to the literature by investigating various aspects of youth involvement in agriculture in Tanzania. For instance, the extant studies have examined youth’s willingness and perceptions to engage in agriculture (Magagula & Tsvakirai, 2019). Youth’s willingness to participate in agricultural training programs in schools and factors for youth engagement in agricultural business (Adeyanju et al., 2021).

Dynamics and determinants of youth participation in agriculture (Kafle et al., 2019) and determinants of youth participation in horticulture agribusiness (Albert et al., 2020). The role of leaders and the education system in supporting youth choice of career in agriculture (Shayo, 2020). Further, meta-analysis confirms that there is a low youth buy-in in the sector. Most of these studies hinge on youth perceptions about agriculture and their decision to engage (Boye et al., 2024; Geza et al., 2021).

The expectation from stakeholder initiatives is to make farming an attractive and profitable career for all and thus make agriculture a crucial sector for ending rural unemployment and town migrations. However, the stakeholders' ardent initiatives have not been met with the enthusiastic buy-in from the youth. The extant institution and infrastructure support that have followed state-led directives have not produced the visionary flow of youth in the agricultural sector. Youth only flow into agriculture if other sectors are not productive (Kafle et al., 2019).

The low response to extant incentives proposes that there might be bottlenecking factors such as problems, challenges, or drivers that influence youth flow in the sector. Thus, this thesis embarks on two tasks; first, we examine the problems and challenges embedded in the agricultural sector. Second, we investigate the factors that nurture youths' positive or negative perceptions about agriculture, hence their intensity involvement in agricultural activities.

It is important to identify the reasons for the low response to initiatives. It enables stakeholders to put in place policy measures and successful campaigns nurturing young people's interests towards agricultural entrepreneurship.

The thesis contributes to the literature on youth involvement in agricultural ventures by analyzing the exogenous factors nurturing perceptions of youths about involvement in agriculture. The factors influencing youth intensity of participation in agriculture are rarely investigated. This study will add to the body of knowledge about the problems, challenges, and drivers that affect youth's decisions to engage in agriculture.

1.4. Agricultural finance

The third essay focuses on the impacts of agricultural finance. It investigates the constraints that small-scale farmers face in the financial markets. Further, it evaluates the impact of agricultural finance on crop productivity. Micro-level crop producers form a larger portion of the farming population and are larger producers of food (URT, 2022a).

Difficulties and hurdles facing the sector and the increasing costs of production per acre increase the demand for agricultural finance. Agricultural finance is increasingly gaining attention since the past two decades (Ellinger & Penson, 2014).

Basically, agricultural finance encompasses two broad financial practices ranging from small to large. Agricultural finance at the micro level is associated with producer and firm-level investment and financing decisions about crops, livestock, and agribusiness. The macro level of agricultural finance deals with policies affecting the financial structure and performance of the national food and fiber system such as macroeconomic, international trade, farm commodity, and resources (Ellinger & Penson, 2014).

This thesis focuses on the micro-levels of agricultural finance in Tanzania, where the sources of agricultural finance include government budgets, development partners, private sectors, and civil society organizations (URT, 2022a). In the advanced economies, agricultural finance comes from commercial banks, the farm credit systems, life insurance companies, farm service agencies, farm-related trade and agribusiness, individuals, and farmer mac (Ellinger & Penson, 2014). Agricultural finance is a key factor for crop agriculture as a source of capital (Ojo et al., 2023). It provides crop producers with capital to invest or expand their operations in farming (Ellinger & Penson, 2014).

With agricultural finance, crop producers can buy important agricultural inputs, search for crop markets, improve farm management, and increase resilience in the present and increasing adverse climatic conditions (Ojo et al., 2023).

However, developing countries are characterized by weak agricultural finance that leads to agricultural credit constraints (Tanti et al., 2022). The agricultural sector is affected by climate change impact, limited capital and access to financial services, multiple taxes and levies, and unpredictable crop prices (Maiga, 2016; URT, 2016a) that make it difficult for smallholder farmers to prosper in terms of crop productivity and income augmentation. They increase crop productivity by expanding farmland, which causes deforestation and land degradation (Mugabe, 2020).

For a long time, smallholder farmers have been practicing subsistence farming and selling some of their harvest to meet their needs (Berger et al., 2017; Bongole et al., 2022; Ojo et al., 2023). Crop producers are characterized by weak credit involvement and lack of collateral, fueling a serious issue in the financial market that restricts their ability to pursue commercialized agriculture (Gikonyo et al., 2022).

Reliable access to finance would improve investment in the agricultural sector, which would improve crop production and income after selling the crops (Acclassato et al., 2021). Subsequently, food security improvement and poverty reduction become a reality (Assouto et al., 2023).

Despite the potential of agricultural finance in agricultural productivity, small farmers are neglected in credit access in the financial market (Gikonyo et al., 2022; Maina et al., 2020; Zougmoré et al., 2016). They are considered risky (URT, 2015), they are a fragile group to deal with (Abedifar et al., 2024), and most of them do not have a credit history in financial intermediaries (Ojo et al., 2023; Tanti et al., 2022).

The co-existence of farmers with different characteristics gives rise to two antagonistic groups of pro-large and pro-small farmers (Acclassato et al., 2021). The financial markets support pro-agribusiness (large farmers) with large investment in agriculture (Ellinger & Penson, 2014). Pro-large farmers consider pro-family farming (smaller farmers) as being too risky and not competitive (Acclassato et al., 2021). The neglect of small-scale farmers by financial intermediaries has fueled a rise of a strand of research in agricultural finance (Acclassato et al., 2021; Gikonyo et al., 2022; Maina et al., 2020). However, the extant literature has not fully discussed the impacts of access to agricultural finance on crop productivity.

The relationship between small-scale farmers' access to finance and their impact on crop productivity has not been fully explored in Tanzania. This gap is addressed in this thesis by investigating the factors affecting small or family farmers' access to credit or loans in the financial markets as a proxy for agricultural finance and how access to credit affects crop yields among smallholder farmers.

The thesis informs how Tanzania, development partners, and the private sector should implement measures regulating financial markets and agriculture in favour of the marginalized small-scale farmers. Investigating the impact of agricultural finance on crop productivity is crucial. It enhances the achievement of national food security and development goals.

Therefore, the thesis contributions align with academic and policy demands. The findings provide valuable policy recommendations to enhance productivity, climate resilience, and youth participation in agriculture in the agricultural transformation and SDGs achievement. Academically, it serves as a reference for subsequent studies in the related areas.

1.5. Structure of the thesis

The rest of the thesis is structured in five chapters. A short overview of every chapter is given below. The thesis contains four papers organized in three themes. All papers have been submitted for publication in authentic journals.

Particularly, Chapter 1 summarizes the thesis's overview. Chapter 2 presents one research papers entitled *"Climate-Smart Agriculture and the Economics of Crop Productivity in Tanzania."* Chapter 3 contains two papers. First paper is entitled *"Drivers of Youth Intensity of Participation in Agriculture: Insights from Tanzania."* The second paper entitled *"Youth Higher Intensity, Higher Gains? Empirical Evidence from Crop Farming in Tanzania."* Chapter 4 consists of the paper entitled *"Impact analysis of agricultural finance on agricultural productivity among smallholder farm households in Tanzania."* Chapters 2-4 are structured with an abstract, introduction, literature review and hypothesis development, data and variable construction, methodology, empirical results, conclusion, references, and appendix. Chapter 5 consists of a summary of the thesis's findings, contributions, limitations, and suggestions for future research directions.

Chapter 2

Climate-smart agriculture (CSA) and its impacts on farm performance

Chapter 2 consists of one research paper that investigates the impact of CSA adoption on crop productivity and income for smallholder farmers. The paper is entitled *"Climate-Smart Agriculture and the Economics of Crop Productivity in Tanzania."* This paper has been submitted to a journal for review. The paper examines the determinants of CSA adoption. Further, the paper investigates the impact of CSA adoption on farm productivity and income. The results show that CSA adoption augments productivity and income. Interestingly, non-adopters would significantly gain productivity and income. Results survive a series of robustness checks and remain consistent after addressing the endogeneity and selection bias using two stages (instrumental variable) and additional control variables. The findings imply that reasonable support measures for CSA adoption can have significant contributions to food security and poverty reduction through increased productivity and income augmentation.

Climate-Smart Agriculture and the Economics of Crop Productivity in Tanzania

Abstract

Climate change hazards and impacts are exacerbating. They threaten crop productivity, farmers' resilience, and GHG emission mitigation. Understanding CSA and applying it in agriculture is crucial. However, the adaptation measures by smallholder farmers are still contextual, particularly whether small-scale farmers adopting CSA boosts crop productivity and income is scanty. This study examines the drivers of CSA adoption and the impacts on farm performance. We used nationally representative data from a sample of 1862 farmers cultivating less than 2 hectares. The endogenous switching regression (ESR) was employed to address selection and endogeneity issues of CSA adoption. Propensity score matching (PSM) was adopted for comparison purposes. The results in both models are consistent that CSA adoption augments crop productivity and farmers' income. Interestingly, if non-adopters had adopted, they would have remarkably gained. Results imply that plausible programs, promotions, campaigns, or

policy support measures to scale up CSA adoption can have significant contributions in transforming agricultural performance. Subsequently, food security, poverty reduction, and farmers' resilience could be more pronounced.

Key Words: Tanzania, climate change impact, climate-smart agriculture, income, crop production, endogenous switching regression model, propensity score matching, farmers

1. Introduction

The hazards and impacts of climate change are overwhelming globally (Ray et al., 2019). The elements of weather, such as temperature are continuously rising, and precipitation patterns are becoming unreliable. Severe events such as prolonged droughts, extreme heatwave, wildfire, floods, diseases and pests, melting glaciers, earthquakes, lake saturation, storms, hurricanes, water shortages, avalanches, human healthcare issues, and season and lifestyle changes are happening (Hussain et al., 2020; Winthrop et al., 2018).

They have persistently threatening anthropogenic activities and lives, ecosystems, biodiversity, animal habitats, land degradation, water bodies, and forests (Hussain et al., 2020). There is a potential increase and may trigger significant damage in future if no reliable measures are taken.

The livelihoods and agricultural economy, especially in the resource-poor countries, are even at higher risk (Huang et al., 2011). Small farmers' well-being and rural economies are affected given that crop markets are interrupted by climate change, which harm food supply (Hellin & Fisher, 2018). Consequently, poverty, hunger, food insecurity, low economic growth, environmental degradation, and unemployment are predominant (FAO, 2017a).

The precedent global population increases, adding more pressure on crop production and food availability. For instance, the global population is projected to hit 9 billion by 2050 (Williams et al., 2016). In 2019, about 821 million people faced food insecurity globally, whereas 236 million people are from Sub-Saharan Africa (FAO, 2019).

Further, the effects of climate change on food security and income are more pronounced in low-income countries whose economies depend on agriculture. Data shows that in 2022 about 2.8 billion people have no access to a healthy diet, and severity is felt more in SSA. For instance, about 71.5% are from low-income, 52.6% are from low middle-income, 21.5% are from upper middle-income, and 6.3% are from high-income countries (FAO, 2024).

The impacts of climate change are projected to have the potentials for cascading beyond the food production systems (Mirzabaev et al., 2023). About 713 to 757 faced hunger in 2023, fuelled by the awakes of the COVID-19 pandemic. Meaning 1 out of 11 people in the globe and 1 out of 5 people in Africa sleep without meals. Hunger is still on the rise in Africa while in Asia, Latin America, and the Caribbean countries have relatively remained stagnant from 2021 to 2024. If no relevant initiatives are taken, about 582 million people will be chronically undernourished globally by 2030 (FAO, 2024).

Climate is crucial for crop productivity (Akter et al., 2022) and for agricultural income generation (Amadu et al., 2020). Various measures have been put in place to mitigate the effect of climate change impact on crop production that improve farmers' adaptive ability, resilience, and efficiency utilization of scarce resources in agricultural activities (Islam & Nursey-bray, 2017).

CSA adoption is the most popular and common adaptable approach in the climatic shocks (FAO, 2013). CSA reduces emissions of greenhouse gas (GHG), increases crop production, and increases farmers' resilience to extreme weather shocks in agriculture (Hellin & Fisher, 2018; Mirzabaev et al., 2023). It is particularly crucial to adopt CSA to improve crop production to meet the demand and supply equilibrium and ensure food security (Hellin & Fisher, 2018) which is likely to improve resilience in adverse climatic conditions.

Food production must increase between 60% to 110% to be able to feed the projected population increase (Pardey et al., 2014). This is possible because CSA does more than augmenting productivity, mitigation, and resilience to farmers (Amadu, et al., 2020). It is a holistic approach that brings together prominent stakeholders (hereof: researchers, farmers, policy makers, societies, and public and private sectors) (Akter et al., 2022; Lipper et al., 2014) in facing the climate-induced shocks.

Further, the adoption of CSA is in pursuit of the 13th SDG (combating the impacts of climate change) and the attainment of its targets (Newell et al., 2019). CSA adoption enhances agricultural transformation by improving farming performance and a sustainable environment.

CSA enhances crop productivity, mitigation, and increasing agricultural resilience when facing the implications of climate change (Bhatnagar et al., 2024).

CSA, as a holistic approach, brought together all stakeholders to take every possible action aimed at increasing awareness and developing strategies for adaptation by promoting environmentally friendly practices (Hussain et al., 2020). There is political will across the globe to adhere to their agreements such as to reduce emissions of GHG. Governments devote funds to enhance climate change adaptation and reinforce policies to promote adoption of climate actions such as CSA adoption in agriculture (URT, 2013).

Coherently, CSA adoption enhance the attainment of the SDGs of ending poverty and hunger, promoting inclusive economic growth, employment, and decent job creation for all (UN, 2015) through agricultural transformation which improves farmers resilience (Amadu, et al., 2020).

However, climate change is considered as a complex problem (Hellin & Fisher, 2019) and a context/location-specific (Ngaiwi et al., 2023) requiring contextual investigation for critical understanding.

To date, several studies have existed about CSA since its introduction as a concept by FAO (FAO, 2010) in Tanzania and the neighbouring countries that share some climatic characteristics. For instance, studies in Kenya investigated determinants of CSA usage and adoption constraints among smallholder farmers (Autio et al., 2021; Musa et al., 2022). In Uganda and Tanzania, Mwongera et al. (2017) evaluated context-specific for local community adoption of CSA technologies.

Further in Tanzania, the literature acknowledges studies about determinants, challenges, the impact of climate change on a crop-specific basis, and the impact of CSA on households' food security (Bongole, 2023; Bongole et al., 2022; Craparo et al., 2015; Jones et al., 2023; Kimaro et al., 2015; Kurgat et al., 2020; Mugabe, 2020; Ogada et al., 2021, 2020; Rowhani et al., 2011).

While stakeholders believe that CSA augments productivity and income, there is scant empirical evidence in Tanzania for smallholder farmers. The linkage between climate change adoption measures with production and the income of smallholder farmers is not clear.

This study examines the determinants of CSA adoption and its effect on crop yields and income in Tanzania using nationally representative data from a sample of 1862 smallholder farmers. The study applied ESR and PSM models that address the weaknesses in impact assessment studies such as potential endogeneity and sample selection bias (Ma et al., 2018).

Therefore, the paper contributes to the literature as follows: First, the paper contributes by advancing the literature on the determinants of CSA adoption and its effects on farm performance and income among small scale farmers.

Second, the paper contributes to the impacts of CSA adoption on crop production and income. The resource-poor community boosts productivity and income through effective adoption of CSA. Eventually, farmers' resilience is improved and the SDGs are attained in given climatic variations (Mwalupaso et al., 2020).

Finally, the paper contributes to the formulation of CSA adoption policy support measures. The analysis on crop specificity confirms the importance of feasible policy support measures. It is crucial to improve specific farmers' adoption and crops production. Crop requirements, climate change impact, and environment for farmers vary (Hellin & Fisher, 2018; Khatri-chhetri et al., 2016).

The rest of this paper is structured as follows: Section 2 consists of the context and background of CSA; section 3 describes the methodology (data, variables, and empirical approach); section 4 presents empirical results, discussion, and limitations, whereas section 5 highlights the conclusion and policy implication.

2. The context and background

2.1. Empirical literature review

CSA has been well researched since the introduction of its idea (FAO, 2010). The adoption of CSA practices in agriculture has been documented in extant literature in different dimensions and capacity. Extant empirical literature outlines the determinants and benefits associated with adoption of CSA. Several studies reveal a correlation between adoption of CSA technologies and improved crop production, farmers' resilience, and mitigation. Further, CSA approach to climate change impacts has attracted cardinal research worldwide (Akter et al., 2022).

For instance, some studies focus on determinants of CSA adoption (Balew et al., 2014; Belay et al., 2022; Berger et al., 2017; A. J. Bongole et al., 2022; Dercon & Christiaensen, 2011; Elizabeth et al., 2021; Habtewold, 2021; Jena et al., 2023; Kifle et al., 2022; Kurgat et al., 2020; Musa et al., 2022; Mwongera et al., 2017; Nyasimi et al., 2017; Ogada et al., 2021; Shemsanga et al., 2010; Teklewold et al., 2013, 2020; Wekesa et al., 2018).

Other studies focus on the challenges or barriers that hinder effective adoption of CSA (Nyasimi et al., 2017; Ogada et al., 2020), whereas other studies investigated the implications of CSA adoption and technological diffusion at farm level (Erekalo et al., 2024) and effects of CSA adoption on reduction of Carbon footprint for sustainable maize production (Feng et al., 2023).

Other studies focus on the impact of CSA adoption on specific crop production. Mostly focusing on maize and the associated impact on income (Amadu et al., 2020; Balew et al., 2014; Belay et al., 2022; Berger et al., 2017; Coderoni & Pagliacci, 2023; Dercon & Christiaensen, 2011; Habtewold, 2021; Jena et al., 2023; Kifle et al., 2022; Murray et al., 2016; Teklewold et al., 2013).

Studies investigated the impact of the adoption of CSA on farmer's resilience, behaviour, policy acceptability, and comprehensiveness (Jena et al., 2023; Rodríguez-Barillas et al., 2024), whereas Bongole et al. (2022) assessed how CSA adoption improves food security. These studies provide insights into how CSA adoption can variably be effective and relatively impact farm performance.

Further, these studies demonstrate limitations such as being contextual specific, mixed results, crop specific, and limited sample size. This means that researchers currently know relatively heterogeneous findings about determinants of CSA adoption and its impacts on farm performance and income in Tanzania. If academics, policymakers, and researchers want to understand factors that drive CSA adoption and the relationship with crop farming and income, then investigating what influences successful adoption of CSA and the impacts on crop yields and income is crucial.

This paper examined the determinants of CSA adoption, the impacts on crop productivity and income using a nationally representative cross section data of 1862 smallholder household farmers in Tanzania. The synthesis of empirical literature shows that crops (maize, paddy, and beans) productivity and income impact of CSA in Tanzania remain scanty. This article embarks on filling this gap.

2.2. The agricultural sector, climate change, and CSA adoption in Tanzania

Agriculture is a key activity for livelihood and the backbone of the Tanzanian economy (Bongole et al., 2022; URT, 2016). Agriculture contributes 28% of GDP, 95% of all food, and about 80% of Tanzanians are involved in agriculture (Gwambene et al., 2023). A large part of this farming population is smallholder farmers who are resource-poor (A. J. Bongole et al., 2020; Gwambene et al., 2023; Ogada et al., 2021). About 65.5% of the workforce is in the sector (URT, 2014), whereas 90% are small-scale farmers cultivating 0.2 to 2 hectares in rural proximities (FAO, 2015).

About 60% of farmers are involved in crop production, 37% deal with mixed farming, and 1% engage in pastoralism. Crops cultivated range from cereals (67%) to legumes (11%), oil and nuts seeds (11%), cash crops (7%), and fruits and vegetables (1%) of land annually (URT, 2014). The mainly produced staple food grains include maize and paddy (Mrema et al., 2023) as well as beans as legumes that restore soil nutrients and are largely consumed (Mutungi et al., 2022). Farm productivity has relatively remained low at about 10% for decades partly due to exacerbating climate change impacts (Irish Aid, 2011).

Agricultural practices in Tanzania depend on the natural settings of rain and temperature with limited irrigation schemes (Kurgat et al., 2020; Ogada et al., 2021). Climate change has altered precipitation and temperature patterns, harming crop production. It is evident that there has been a decline in rainfall of 2.8 mm which is 3.3% over 10 years, and temperature has increased by

1.0^0C since 1960 (Winthrop et al., 2018). It is further projected that mean annual temperature will increase by 1.0^0C to 2.7^0C within the 2060s and 1.5^0C to 4.5^0C within the 2090s (Winthrop et al., 2018).

Following the climate change impact, smallholder farmers experience low crop productivity, strained water resources, and increased incidence of pests and disease (A. J. Bongole et al., 2020; Jones et al., 2023). In future, a change in temperature by 2^0C is projected to lower yields by 13%, 8.8%, and 7.6% for maize, sorghum, and paddy, respectively by 2050 (Rowhani et al., 2011). Severe impacts will be in Africa and Asia, coupled with yield declines that are expected to reach 7% in potential food-growing zones within 2030 (WB, 2015).

Farmers who are resource-poor suffer and are proportionately affected by climate change impact given their low resilience capacity (Amadu et al., 2020). It is expected that the situation will be worse for smallholder farmers who have no agricultural technological support (Jones et al., 2023). Without action, it is projected that climate change will add 2.6 million Tanzanians into the poverty pool within the 2050, and 27% of the population and 29.4% from the vulnerable societies have already experienced at least one climate change shock (World Bank Group, 2024).

Tanzania is vulnerable to climate risks due to reliance on rainfed agriculture, low crop productivity agriculture, urban-rural inequalities, unprecedented population increase (Jones et al., 2023), and limited infrastructure in energy, transport, and digital connectivity (World Bank Group, 2024). Acute food insecurity is predominant, hitting at 54.6% (64% and 84% for urban and rural, respectively) (World Bank Group, 2024).

To this end, the major challenge hinges on addressing the synergy and trade-offs between improving crop productivity, resilience to extreme climate change, and greenhouse gas mitigation. Planned CSA adoption enhances synergies and trade-offs between production, adaptation, and mitigation (Ali & Erenstein, 2017). A clear trade-off addresses economic, environmental, and social challenges for effective, efficient, and equitable food systems functioning (Lipper & Zilberman, 2018).

There are many initiatives to promote CSA as responses to climate change impacts and hazards (Akter et al., 2022; Jones et al., 2023). They range from policies, programs, and research that aim at improving adaptive strategies that support food security, income, and strengthen resilience in the face of climate change variability. For instance, in Africa, CSA is in the declarations of The African Union Malabo Declaration (Daum et al., 2022; Lipper et al., 2018), that sets plans and targets to achieve productivity, resilience, and mitigation in agricultural activities (Jones et al., 2023; URT, 2017).

Particularly, in Tanzania the initiatives range from national level to specific agencies that enforce national adaptation plans, nationally determined contributions, and major national investment (Jones et al., 2023). Additionally, CSA is promoted by government institutions, national agricultural research institutions, nongovernmental organizations (NGOs), academic institutions, research organizations, and development partners at varying capacities (Lamanna et al., 2016).

The Tanzanian government has been actively promoting CSA adoption in sectoral and multi-sectoral policies. For instance, the CSA program 2015-2025, Agriculture Climate Resilience Plan (ACRP), Tanzania Agricultural Research Institute (TARI), Sokoine University of Agriculture (SUA), Ruvuma Commercialization and Diversification of Agriculture (RUCODIA), and the District Councils, and the Agricultural Sector Development Plan II (ASDPII) with several CSA targets and plans to be achieved by the agricultural sector within 2030 (Lipper & Zilberman, 2018; Newell et al., 2019; Rioux et al., 2017; The Alliance for a Green Revolution in Africa (AGRA), 2015; URT, 2015).

International organizations working with the government of Tanzania to bring CSA practices into reality include the African Green Revolution Alliance (AGRA), One Acre Fund, SNV-Tanzania, the African Conservation Tillage Network (ACTN), and the Consultative Group on International Agricultural Research (CGIAR), which works along with the United Nations-Food and Agriculture Organization (UN-FAO) around the globe (Jones et al., 2023). The ACRP and ASDPII are the largest government initiatives which have nationwide coordination to promote

CSA adoption to farmers to ensure food security, poverty reduction, farmer resilience, and stable disaster management (Jones et al., 2023). Farmers are encouraged and supported in various ways to adopt appropriate CSA practices in a particular location given the resources and time of the threatening climate conditions.

Technology is climate smart if it can enhance the attainment either production, adaptation, or mitigation. It can be traditional, innovative, or imported (Khatri-chhetri et al., 2016). A smallholder farmer is considered a CSA adopter if he/she implements CSA practices directly and indirectly following the initiatives promoting CSA adoption. A farmer must have used the technologies in farming for all land cultivated maize, paddy, or beans.

The CSA technologies promoted include knowledge and skills-smart (crop planting timing, improved seeds, credit/loans and farmers' income, farm inputs and outputs, and education/training), weather-smart (technological advancement, crop agro-advisory, mobile phones, television (TV), radio, and the internet), carbon-smart (integrated pest management and agroforest), nutrient-smart (crop diversification, organic manure), energy-smart (minimum tillage and solar energy use), and water-smart (drip irrigation, channel (furrow) irrigation, bed planting, cover crops method, rainwater harvesting, and drainage management) (Bongole et al., 2022; Khatri-chhetri et al., 2016; Li et al., 2019)

The adoption of the CSA is voluntary and is generally low (some adopt and some do not adopt) (Jones et al., 2023; Bongole et al., 2022; Mwongera et al., 2017; Lamanna et al., 2016). Despite the various stakeholders' ardent efforts, they have not won the enthusiastic wide practice of CSA from farmers. The state sectoral-led, and development partners' initiatives have not resulted in farmers' wide application of CSA technologies. Lower response to stakeholders' promotion of CSA alert could be persistent factors unaddressed and its impact of farm performance.

3. Methodology

3.1. Data sources and variables

This study uses secondary data from the National Sample Census of Agriculture (NSCA) of 2020 of Tanzania (NBS, 2020). The sampling procedures adopted a framework for household-level surveys of Tanzania which involves some stages. The first stage selects the rural and urban enumerated areas (EAs) as Primary Sampling Units (PSUs) by sorting the regions and districts before probability proportionate to size (PPS). The second stage selects agricultural farming households from EAs for data collection.

The probability of a household being interviewed depended on the number of households in a particular EA and were randomly selected. With respect to the sampling design, a total of 33,808 households were sampled in this national survey. Data was collected using structured questionnaires.

To avoid the bias in recalling the information/data by farmers, the survey was conducted immediately after farming seasons. Also reported financial information about income and off-farm income was obtained by observing and recording the harvests in terms of kilograms and recording the harvest values reflecting the prevailing prices in the market.

We further screened the data to obtain a data set that best fits our research questions and is good for comparison between adopters and non-adopters of CSA. During data cleaning, we considered only smallholder farmers who were involved in full-time agriculture, smallholder farmers who mainly produce maize, paddy, or beans as staple food and sales, smallholder farmers who experienced climate change shocks such as drought in the past, and farmers who cultivated less than 2 hectares.

We obtain a sample of 1862 smallholder farmers who meet the international standards that smallholder farmers are those who cultivate less than 2 hectares (Acclassato et al., 2021; FAO, 2015; Noltze et al., 2013; TNCFI, 2017). The study focuses on smallholder farmers because they occupy a large segment of the farming population and produce a large share of food (FAO, 2015; Roop et al., 2023).

The study adopted variables from the extant literature about CSA adoption. Outcome variables and the covariates are described, and the sources of each variable are elaborated in Table 1.

The variables in this paper are consistent with the past studies (Akter et al., 2022; Amadu et al., 2020a; Bongole, 2022; Lamanna et al., 2016; Noltze et al., 2013). Smallholder farmers' CSA adoption status is a dummy variable, where 1 represents adopters and 0 for non-adopters. Summary of statistics and descriptions of the variables is contained in Table 1.

Several variables are statistically significantly indicating the different between the two regimes, as in the cases in other studies (Abdulai, 2016; Akter et al., 2022; Amadu et al., 2020). The results give an insight into the possibility of self-selection between the two groups. The use of ESR model is appropriate to address the possibility of selection bias.

Table 1. Summary of statistics

Variables	Descriptions	Indicative reference	Adopter	Non-adopter	Difference
Outcome variables					
All crops output	Total Kg (Maize, Paddy, Beans)	(Mukasa et al., 2017; Akter et al., 2022; Amadu et al., 2020a)	2872.785	1227.633	1645.151***(40.054)
Maize	Total Kg (Maize)	(Akter et al., 2022; Bouteska et al., 2024; Lamanna et al., 2016)	2285.789	1053.469	1232.321***(50.319)
Paddy	Total Kg (Paddy)	(Akter et al., 2022; Lamanna et al., 2016; Noltze et al., 2013)	2710.396	1229.222	1481.174***(89.996)
Beans	Total Kg (Beans)	(Akter et al., 2022; Bouteska et al., 2024; Lamanna et al., 2016; Siamabele, 2021)	701.941	370.987	330.954***(60.822)
Household income	Total household income in Tanzanian Shillings (TZS)	(Akter et al., 2022; Amadu et al., 2020; Belay et al., 2022; Lamanna et al., 2016; Noltze et al., 2013)	13.534	12.68	.855***(.043)
Maize(income)	Household income in TZS (Maize)	(Abdulai, 2016; Akter et al., 2022)	12.923	12.108	.815***(.044)
Paddy (income)	Household income in TZS (Paddy)	(Akter et al., 2022; Noltze et al., 2013)	13.610	12.773	.837***(.057)
Beans (income)	Household income in TZS (Beans)	(Bouteska et al., 2024)	14.197	13.824	.374***(.12)

Agricultural Inputs					
Herbicide	If household uses herbicides: 1=used; 0 = otherwise.	(Lamanna et al., 2016; Noltze et al., 2013)	0.169	.216	-.048***(.018)
lnQnty_seedKg	Quantity of seeds used in Kg	(Lamanna et al., 2016; Noltze et al., 2013)	2.551	2.358	.193***(.038)
LnTotlQtyFertilizerMPB	Total quantity of chemical fertilizers in Kg	(Lamanna et al., 2016; Noltze et al., 2013)	1.605	.698	.907***(.088)
LnLandSize	Household's total land in hectares	(Abdulai, 2016; Akter et al., 2022; Noltze et al., 2013)	0.822	.618	.205***(.038)
Manure	If household used manure:1=used; 0 = otherwise.	(Lamanna et al., 2016)	0.649	.564	.085***(.022)
Socioeconomics					
gender	Sex of the farmer: 1 = male; 0 = female	(Akter et al., 2022; Nyasimi et al., 2017)	0.736	.588	.148***(.022)
age	Age of a household member in years	(Abdulai, 2016; Akter et al., 2022)	46.819	50.597	-3.777***(.723)
LnNumber_male	Male adults in a household	-	0.623	.532	.09***(.027)
LnNumber_female	Female adults in a household	-	0.708	.666	.042(.027)
crop_failre	Crops failure in the past season: 1=Yes; 0 = No.	(Akter et al., 2022; Amadu et al., 2020a)	0.305	.349	-.044**(.022)
lnHhSize	People in a household	(Akter et al., 2022; Bongole et al., 2022; Teklewold, 2023)	3.682	3.631	.051(.044)
Off_Fmincome	Involved in paid off-farm activity: 1=Yes; 0 = No.	(Akter et al., 2022; Amadu et al., 2020; Tambo & Wünscher, 2018)	0.450	.349	.101***(.022)
lntotal Lvstok	Total number of livestock as assets	(Erekalo et al., 2024)	0.149	.107	.043**(.02)
Access status					
LnDstnce_Markt	Distance to market (Km)	(Abdulai, 2016; Akter et al., 2022; Belay et al., 2022)	2.168	2.347	-.177***(.052)
Institutional					
Crdit_accss	Farmer received credit: 1 = Yes; 0 = No	(Abdulai, 2016; Marenya et al., 2017; Rodríguez-Barillas et al., 2024)	0.057	.034	.024**(.009)
Biophysical status					
LnDstnce_Home	House to farm distance (Km)	(Akter et al., 2022)	5.617	4.719	.898**(.355)

LnDstnce Road	Farm to road distance (Km)	(Kurgat et al., 2020)	1.126	1.174	-.048(.042)
IVs					
Years_Educ	Years spent in schooling	(Abdulai, 2016; Akter et al., 2022)	6.064	3.885	2.179***(.163)
GrandC ostsMPB	Total input costs	(Abdulai, 2016; Lamanna et al., 2016; Noltze et al., 2013)	130757.705	59901.811	70855.894***(5499.123)

Notes: *, ** and *** represent significance level of 10%, 5% and 1%.

Source: National sample census of agriculture (NSCA) 2020 from Tanzania

3.2. Theoretical review and the conceptual framework

The study is guided by utility and production theories. Utility theory reveals individuals' preferences. It is assumed to explain the small farmers' behaviour (Akter et al., 2022). It claims that choice is made based on maximum satisfactions attained (Fishburn, 1970).

Farmer's satisfaction refers to the gains obtained from crop productivity and income. Small farmers' CSA technology adoption is binary. A small farmer may decide whether to adopt or not. The decision is based on the satisfaction maximization emanating from the impact of CSA technologies on crop productivity and income gains. Benefits of adopters is Y_{1i} in comparison with non-adopters which is Y_{0i}. Small farmer i^{th} can opt to adopt CSA technologies if $Y_{1i} > Y_{0i}$ and the net gain is U_{1i}>0. Despite farmers' preference and CSA adoption is clear to farmers and researchers through observation, but the net benefits accrued by farmers are unobservable.

Thus, $U_{1i}^{*} = Y_{1i} - Y_{0i} > 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (i)$

The production theory describes crop productivity per hectare given agricultural inputs, other factors (CSA technologies) at a particular level of technology (Forsund et al., 1980; Missiame et al., 2021). It demonstrates the technical combination of agricultural inputs with crop productivity as well as the optimal crop productivity at a fixed level of inputs (Lovell, 1993; Farrell, 1957) so that variables impacting the productivity are realized (Meeusen & van Den Broeck, 1977). It advances the Cobb-Douglas production function in its first order condition which can be expressed as:

$$Y_{1i} = AL^{\alpha 1i} K^{\alpha 2i} Q^{\alpha 3i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (ii)$$

Where; Y_{1i} is a crop productivity per hectare, A is a constant term, L is labour employed (adult males and females farmers), K is capital (hereof fertilizers, seeds, land), Q summarizes biophysical factors (distance to farm) and other factors used in production (hereof socio-economics and institutional) while $\alpha 1i$, $\alpha 2i$ and $\alpha 3i$ are estimated vector elasticities.

CSA adoption improves productivity, farmer' resilience, farm and crop management, and delegation of farm tasks, and farmers engage in paid off-farm activities (Akter et al., 2022; Amadu et al., 2020; Rasheed et al., 2020). Therefore, the impact of CSA technologies on crop productivity follows that net benefit in eqn. (i) is determined by observable variables (hereof biophysical, institutional, and socioeconomics) and the unobservable factors such as motivations or preferences affecting farmer decision ε_i such that.

$$U_i^* = \beta X_i + \gamma G_i + \varepsilon_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . (iii)$$

Where: U_i^* is crop productivity of i^{th} smallholder household farmer, Xi is a vector of farm and socio-economics profiles (hereof gender, age, education, household size etc), G_i is CSA technologies adoption status of each i^{th} farm household, β and γ are coefficients to be estimated, and ε_i is the error term with zero mean and constant variance δ^2

Further, smallholder farmer's satisfaction is a function of observable factors (farm inputs, socio-economic, biophysical, and institutional) and unobservable (preference, inborn techniques, motivation, social network, management skills, experience, or risks) (Abdulai, 2016; Akter et al., 2022; Amadu et al., 2020a).

With respect to climate change impact and stress, farmers' agricultural production decisions are claimed to be dependent. We assume that farmers are risk neutral. The insight into whether adopting CSA improves crop productivity and income after selling crops is the foundation of their decisions. CSA adoption enables greater plant uptake of nutrients and organic matter, prevents soil erosion, and the use of improved seed (Jones et al., 2023) augments crop productivity and income after the sale of the increased crop harvest (Akter et al., 2022; Noltze et al., 2013).

We contribute to the existing literature by investigating the determinants of CSA adoption and its impact of CSA on crop productivity and income. We constructed the following hypotheses (see H1 and H2) and the conceptual framework in Fig. 1. We can compose them based on extant theoretical and empirical literature.

H1: Factors such as socio-economic, farm inputs, biophysical, and institutional affect CSA adoption, crop productivity, and income.

H2: CSA adopters get higher crop productivity and income than non-adopters.

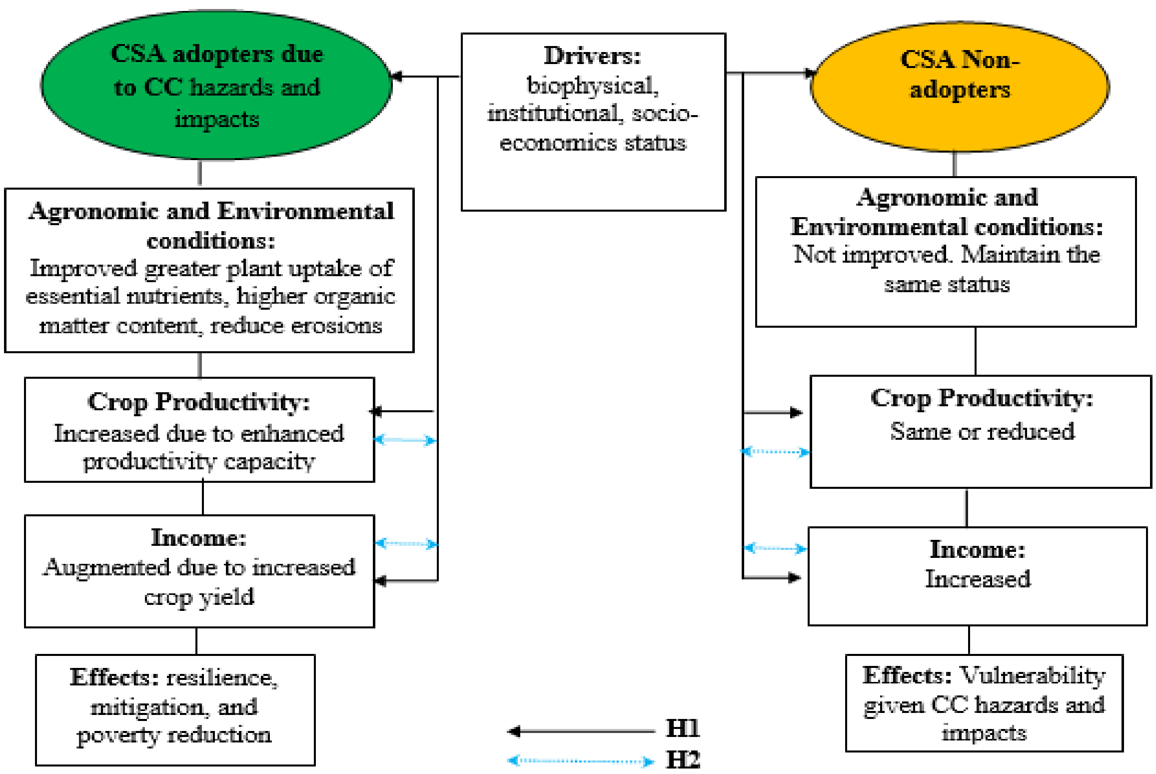

Figure 1. The conceptual framework

Source: Authors 2025

3.3. Econometric model

3.3.1. Decision to adopt CSA technologies

The ESR has the power to account for endogenous factors due to selection bias in impact assessment (Shahzad & Abdulai, 2020). This article estimates crop productivity (hereof, maize, paddy, and beans) and income in Tanzania while accounting for endogeneity of CSA and selection bias. ESR is an instrumental variable (IV) approach that clears endogeneity and selection bias with no restriction of typical IV techniques (Coulibaly et al., 2017). The ESR model is a Heckman selection correction approach that treats the problem of selection bias as an omitted variable (Heckman, 2013).

The ESR model involves two dependent variables (adopters and non-adopters). In line with random utility maximization theory, the study assumes that Tanzanian farmers are risk neutral, and they can choose to be either adopters or non-adopters given the anticipated crop productivity and income.

Thus, farmers' decision-making to adopt CSA technologies depends on the perception of whether it will maximize gains or not. Net crop productivity and income are unobservable (latent) variable $\Lambda i*$ containing the differences between crop productivity and income for CSA adopters ($\gamma 1i$) and non-adopters ($\gamma 0i$) respectively. A rational household i^{th} will adopt CSA technologies if and only if the anticipated net benefits are high in Eqn. (i). It follows that: -

$$\Lambda i *= \gamma 1i - \gamma 0i > 0 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (iv)$$

Where, $\Lambda i*$ the function of observed variables such as farmer demographics, socio-economic status, institutional, and biophysical. The study models the CSA technologies adoption decision in unobservable knowledge, adopting the procedures from Amadu et al. (2020) in Malawi and Akter et al. (2022) in Bangladesh such that:

$$\Lambda i * = \alpha\gamma i + \mu i \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (v)$$

Where: α is a vector of parameters to be estimated

γi is a vector of independent variables

μi is an error term (vector of unobserved factors affecting the adoption decision)

We only observe the CSA adoption status Λi as

$$\Lambda i = \begin{cases} 1 \quad if\ \Lambda i *> 0, \\ 0 = if\ \Lambda i * < 0, \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . \ldots \ldots \ldots \ldots . \ldots \ldots . \end{cases} (vi)$$

Where: Λi is a binary variable, 1 for CSA adoption by i^{th} farmer and 0 if otherwise.

3.3.2. Small farmer impact evaluation and selectivity bias

A farmer who decides to adopt or not, the net benefits on crop productivity and income can be expressed as in Eqn. $(viia)$ and Eqn. $(viib)$ conditional on Λi respectively:

CSA adopters' regime:

$$\gamma 1i = \pi 1 \times 1i + \omega 1i, if\ \Lambda i = 1 \ldots \ldots \ldots \ldots . . \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . \ldots (viia)$$

Non adopters' regime:

$$\gamma 0i = \pi 0 \times 0i + \omega 0i, if\ \Lambda i = 0 \ldots \ldots \ldots \ldots \ldots \ldots \ldots . \ldots \ldots \ldots \ldots \ldots . \ldots \ldots (viib)$$

Where: $\gamma 1i$ and $\gamma 0i$ are crop productivity or income corresponding to adopters and non-adopters of CSA for the i^{th} smallholder farmer.

$\pi 1$ and $\pi 0$ are vectors of parameters to be estimated.

$\times 1i$ and $\times 0i$ are vectors of variables influencing crop productivity and income for the i^{th} smallholder farmer, $\omega 0i$, and $\omega 1i$ are error terms.

Vectors in $\times i$ may overlap with vectors of determinants of γi (Amadu et al., 2020a; Akter et al., 2022).

Proper identification was achieved by making sure that at least some variables are excluded in γi. Years of schooling and total agricultural input costs were the instrumental variables (IVs), and a test was conducted to confirm their validity as IVs. The IVs were statistically significant correlated with CSA technologies adoption (0.029 and 0.0295(p<1%)) but not with smallholder farmer income (-0.0034(p=0.999)) and productivity (-0.0070(p=0.991).

The random disturbance term μi in eq. (v) and the $\omega 1i$ in eq. $(viia)$ and $\omega 0i$ in eq. $(viib)$ are assumed normally distributed with zero mean and a covariance matrix which is non-singular (Fuglie & Bosch, 1995) such that:

$$Cov(\mu_i, \omega_{0\,i}, \omega_{1\,i}) = \begin{pmatrix} \sigma_i^2 & \sigma_{i0} & \sigma_{i1} \\ \sigma_{i0} & \sigma_0^2 & \sigma_{10} \\ \sigma_{1i} & \sigma_{10} & \sigma_1^2 \end{pmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (viii)$$

Where:

$\sigma_{10} = cov\ (\omega_1 . \omega_0)$, $\sigma_{1i} = cov\ (\omega_1 .\ \mu_i)$, and $\sigma_{0i} = cov\ (\omega_0 . \mu_i)$ are covariances, respectively. $\sigma_i^2 = var\ (\mu_i)$, $\sigma_0^2 = var\ (\omega_0)$, $\sigma_1^2 = \ var\ (\omega_1)$ variances. Further, σ_1^2, σ_0^2, and σ_μ^2 variances that equal to one (Greene, 2003) of the random terms μ_i, $\omega_{0\,i}$, and $\omega_{1\,i}$, respectively.

The adoption of CSA technologies is non-random. The unobservable (preference, inborn techniques, motivation, social network, management skills, experience, or risks) variables are only realized by smallholder farmers, not the researcher. The researchers observe status reported by the farmers during the survey.

In this context, there is potential selection bias emanating from endogeneity of CSA adoption based on non-random observed and unobserved features for self-selection into groups of adopters and non-adopters (Amadu et al., 2020a). If this scenarios holds, means that the group of adopters and non-adopters are systematically different (Issahaku & Abdulai, 2019). Accordingly, the unobserved features in the outcome eqns. ($viia$ and $viib$) are related to the random term in the selection eqn. (v), then the impact of CSA adoption on productivity and income are expected to be biased in failure to address selection bias.

The endogeneity and selection bias are addressed in the literature by applying the IV techniques or a generalized Heckman selection correction technique (Akter et al., 2022). We applied the same technique in the context of the omitted variable problem, accounting for selectivity bias and unobserved heterogeneity (Akter et al., 2022; Amadu et al., 2020).

In particular, the inverse Mills ratios or selection terms from the selection eqn. for the adopters and non-adopters are realized (Heckman, 2001). The outcome variables $\gamma 0i$ and $\gamma 1i$ are assumed not simultaneously observed, then $\sigma 10$ is assumed 0. Given the sample selection effects, the values of error terms in eqns. $(viia)$ and $(viib)$ are non-zero due to conditional on selection criteria (Maddala, 1986). Estimation using ordinary least squares (OLS) would result in a biased estimate of outcome variables of $\gamma 0i$ and $\gamma 1i$ (Lee, 1982). Thus, the error term in eqns. ($viia$ and $viib$) $[\omega 1i|\Lambda i = 1]$ and $[\omega 0i|\Lambda i = 0]$ are condensed as:

$$E[\omega_{1_i}|\Lambda_i = 1] = \sigma_{1\mu}\frac{\emptyset[\alpha\gamma_i]}{\phi[\alpha\gamma_i]} = \sigma_{1\mu}\tau_{1i}, \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (ixa)$$

$$E[\omega_{0_i}|\Lambda_i = 0] = -\sigma_{0\mu}\frac{\emptyset[\alpha\gamma_i]}{1 - \phi[\alpha\gamma_i]} = \sigma_{0\mu}\tau_{0i}, \dots\dots\dots\dots\dots\dots\dots.\dots\dots (ixb)$$

Where:

$\tau_{1i} = \frac{\emptyset[\alpha\gamma_i]}{\phi[\alpha\gamma_i]}$ and $\tau_{0i} = \frac{\emptyset[\alpha\gamma_i]}{1-\phi[\alpha\gamma_i]}$ are the standard normal probability density function (pdf)

$\emptyset(.)$ and $\phi(.)$ are standard normal cumulative distribution function (cdf).

τ_{1i} and τ_{0i} constitute the inverse Mills ratios evaluated at $\alpha\gamma_i$.

To determine the impact of CSA adoption on crop productivity and income, the study estimates the expected values for actual (real data) and counterfactual scenarios. The average treatment effect on the treated (ATT) and untreated (ATU) was estimated for CSA adopters and non-adopters (for actual and their counterfactual scenarios) as follows:

For CSA technologies adopters (actual data/observed):

$$E(\gamma_{1iAdopter}|\Lambda_i = 1) = \alpha_{1A} \times_{1i} + \sigma_{1\mu}\tau_{1i} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (x)$$

For CSA Adopters had they not adopted (counterfactual) or “what if they did not adopt”:

$$E(\gamma_{1iNon-adopters}|\Lambda_i = 1) = \alpha_{1N} \times_{1i} + \sigma_{10}\tau_{1i} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (xi)$$

For non-adopters of CSA technologies (real data/observed):

$$E\left(\gamma_{1i\text{Non-adopters}} \middle| \Lambda_i = 0\right) = \alpha_{1N}\, X_{1i} + \sigma_{10}\tau_{10i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (xii)$$

For non-adopters had they adopted CSA (counterfactual) or "what if they adopted":

$$E\left(\gamma_{1iAdopters} \middle| \Lambda_i = 0\right) = \alpha_{1A}\, X_{1i} + \sigma_{1\mu}\tau_{1i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots (xiii)$$

Eqns. (x) to (xiii) have τ_{1i} constant meaning that outcome variables estimation, ATT (change in productivity and income following CSA adoption) and ATU (change in productivity and income due to CSA non-adoption account for unobserved factors. The estimation of outcome variables depends only on observable factors. All the unobservable influences $(\sigma_{1\mu} - \sigma_{0\mu})$ and $(\sigma_{1\mu} - \sigma_{0\mu})$ are cancelled out as applied by (Abdulai & Huffman, 2014; Amadu et al., 2020; Akter et al., 2022) is obtained by eqn. (xi) minus eqn. (xii) and eqn. (xiv) subtract eqn. $(xiii)$. $(xiii)$ provide the change in crop productivity and income due to CSA adoption and non-adoption respectively.

Thus, the "average treatment effect on the treated" (ATT) and untreated (ATU) are computed as:

$$ATT = E\left(\gamma_{1iAdopter} \middle| \Lambda_i = 1\right) - E\left(\gamma_{1i\text{Non-adopters}} \middle| \Lambda_i = 1\right) = x_{iAdopter}(\alpha_A - \alpha_N) + \tau_{ai}\left(\sigma_{1\mu} - \sigma_{10}\right) \ldots\ldots (xiv)$$

$$ATU = E\left(\gamma_{1iAdopter} \middle| \Lambda_i = 0\right) - E\left(\gamma_{1i\text{Non-adopters}} \middle| \Lambda_i = 0\right) = x_{i\text{Non-dopter}}(\alpha_A - \alpha_N) + \tau_{ni}\left(\sigma_{1\mu} - \sigma_{10}\right) .. (xv)$$

3.3.3. Controlling bias affecting CSA technologies adoption

The estimates of the effect of CSA technologies adoption on outcomes may bear bias emanating from three important sources: a) endogeneity of CSA technologies following the self-selection, b) bias emanating from the existence of the endogenous covariates that confound the effect, such as off-farm income, and c) policy/promotion/emphasis implementation bias. If the biases are ignored, the impact of CSA technologies adoption on outcomes may be biased.

The bias stemming from self-selection is addressed by applying the ESR model. The bias emanating from endogenous covariates, which are likely to influence the effect of the adoption of the CSA technologies on outcomes, is that the covariates are jointly determining the CSA adoption (Shahzad & Abdulai, 2020) dealt with in this paper.

In our case the covariate confounding the impact of CSA on outcomes is off-farm income. The existence of scarce resources to enable smallholder farmers to adopt CSA and paid-off-farm activities influences CSA adoption and eventually affects the outcomes just like in the previous studies (Amadu et al., 2020; Akter et al., 2022).

The same in our case, off-farm income influenced the adoption of CSA. We applied the two-stage Control Function (CF) strategy to deal with endogenous covariates as detailed in Amadu et al. (2020a), in Akter et al. (2022), in Issahaku & Abdulai (2019), and in Wooldridge (2015). In our context, the first stage used dummy off-farm income 1 if the farmer had engaged in paid activities other than agriculture and 0 otherwise.

It was regressed in conjunction with other independent variables in outcomes. The second stage is the choice eqn. of the ESR model, where residual variables from the first stage are included as independent variables. The residuals are statistically insignificant, and the endogenous covariates are realized (Wooldridge, 2015).

The study thought of a crucial way to fully satisfy the exclusion restriction, and this is depicted by the statistical insignificance and significance of the instrumental variables (IVs) in outcomes (first stage) of the control function and the second stage (choice), respectively (see Table A for details).

The bias due to policy/promotion/emphasis was addressed during the sampling when the NSCA survey was conducted. We are aware that the policy/promotion/emphasis on the use of CSA technologies in agriculture is for all farmers in their respective areas. The grouping of the participating and non-participating based on randomly collected data from the NCSA 2020 is different from somewhere else in Malawi by Amadu et al. (2020a) and in Bangladesh by Akter et al. (2022).

The approach used in this study reflect a study by Abdulai (2016) in Zambia, thus we obtained the adopters and non-adopters from the entire population of farmers in Tanzania, making sure that the sample selection really represents the true population. In this context, the adopters and non-adopters' dwell in the same localities in all sampled areas and have the same characteristics to realize the impact of CSA.

There are no naturally existing control and treated groups as a unique intervention program requirement, as in the works of Amadu et al. (2020) and Akter et al. (2022), that have adopters and non-adopters participating villages in a program. Impliedly, the policy/promotion/emphasis of CSA technologies adoption to all farmers and the random sampling of all farmers makes the adopters, and non-adopters share similar observable characteristics, which possibly reduce endogeneity and selection that are likely to originate from various programs emphasizing farmers to apply CSA technologies. The sampling strategy enables us to estimate the model by assigning 1 for adopters and 0 otherwise.

4. Empirical results and discussion

4.1. Factors influencing CSA adoption

The results of the ESR are summarized in Table 2. The estimation from the first stage depicts that the determinants of CSA adoption range from agricultural input availability and usage, socio-economic factors, and access factors. Chemical fertilizers, land size, number of females, distance to the market, and years of education are important factors. Distance to the market negatively influences CSA adoption. Access to the market enables farmers to access other farm inputs and knowledge about farming (Akter et al., 2022; Mwalupaso et al., 2020). The farmers dwelling far from the market are less likely to adopt CSA technologies.

Land size plays a great role in influencing the use of CSA technologies. Farmers feel that without CSA technologies adoption, land alone cannot improve productivity in the face of climate change variations. Land size increases the propensity to adapt CSA practices and is consistent with the study in Bangladesh that land is positively related to CSA adoption (Akter et al., 2022).

In the African context, especially in rural areas women are a great source of farming labour. The number of adult females in a household is greatly associated with CSA adoption. Farmers who frequently involve themselves in agriculture as a source of their livelihood and income are more likely to adapt to CSA technologies. Results are in the light of the findings by Teklewold et al. (2020) that women involved in agriculture frequently and are likely to adopt CSA.

The instrument (years of schooling) in CSA for the criteria function is positive and statistically significant. Education of a household head influences CSA adoption due to knowledge and awareness of impacts or threats of climatic change on soil fertility, and the propensity to adapt depends on awareness of the severity of the climatic shocks, resources availability, and other coping strategies.

Education suggests that CSA adoption is confined by lack of awareness of the broad goals of CSA that solve issues more than maintaining soil nutrients (FAO, 2017b). Education or training programs increase awareness and adoption of CSA. Education is revealed as crucial in acquiring new knowledge, skills, and technologies for the improvement of crop productivity. The same observations were obtained in Zambia by Abdulai (2016).

Further, off-farm income residual is negatively and statistically insignificant, implying that estimates are bias-free from the endogenous variables. We employed the ESR model, the second stage specifies the production function, where the part of the diagnostic test confirms that the model fits the data. Furthermore, heterogeneity is confirmed in Table 2 at the bottom that would alter the result to inconsistency and biased if not addressed. This validation confirms the use of ESR as a better way of identification against other methods.

Table 2. Estimation results of the ESR model

Determinants of CSA adoption		Second stage estimation of the ESR.	
Variables	Coef. estimates (standard errors)	Adopters Coef. estimates (standard errors)	Non-adopters Coef. estimates (standard errors)
Constant	-1.550* (0.820)	3369.758*** (344.500)	1310.487***(177.341)
Agricultural Inputs			
Herbicide	-0.175(0.106)	-124.989(83.876)	-127.454**(61.197)
lnQnty_seedKg	0.018(0.053)	-33.395(44.338)	14.651(32.428)
LnTotlQtyFertilizer	0.100***(0.032)	34.755(21.627)	29.209*(17.251)
MPB			
GrandCostsMPB	0.000(0.000)	0.001***(0.000)	0.001**(0.000)
LnLandSize	0.115**(0.057)	-175.569***(38.407)	-121.423***(33.720)
Manure	0.112(0.092)	-45.066(72.596)	28.049(52.131)
Socioeconomics			
gender	0.095(0.110)	158.749*(83.761)	20.315(56.559)
age	0.005(0.007)	-1.271(2.295)	-3.313**(1.611)
LnNumber_male	0.039(0.058)	-58.113(56.994)	-38.923(45.158)
LnNumber_female	0.035*(0.055)	1.088(54.228)	-72.331*(43.273)
crop_failre	-0.040(0.067)	15.264(68.565)	17.168(50.804)
lnHhSize	0.040(0.034)	-76.912**(32.232)	-11.008(24.784)
Off_Fmincome	1.406(1.477)	-84.159(66.337)	33.677(51.718)
Access status			
LnDstnce_Markt	-0.082***(0.029)	-45.316(31.222)	45.324**(21.594)
Institutional			
Crdit_accss	0.222(0.153)	172.811(135.499)	-28.491(133.729)
Biophysical status			
LnDstnce_Home	0.002(0.006)	1.540(3.766)	14.662***(3.594)
IVs			
Years_Educ	0.055**(0.026)		
Off_fmincomeResdl	-1.337(1.478)		
Statistical diagnostics			
LR test of indep. eqns.: chi2(1)	0.22		
Prob > chi2	0.6407		
Log likelihood	-16210.56		
sigma_1		931.226***(22.023)	
sigma_2			720.842***(17.385)

rho_1		-0.034(0.250)	
rho_2			0.074(0.151)
N	1857	1857	

*, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

Source: NCSA of Tanzania 2020

Regimes one and two appear in the third and fourth columns of Table 2, respectively. The cost of input is positive and statistically significant, influencing crop productivity. The relatively low cost improves productivity by improving the uptakes of important agricultural inputs for both adopters and non-adopters of CSA technologies. Input uptake or usage greatly influence involvement in agricultural activities and productivity. Relatively low cost of agricultural inputs allows farmers to use more inputs and improve productivity (Noltze et al., 2013).

Furthermore, land and household size are negatively and statistically significant. Land is related to productivity; implying that land is not the only factor increasing productivity. Land is a significant input but must be combined with other inputs. Inputs such as chemical fertilizers improve the quality of soil and fertility, leading to increased productivity. Large family size negatively contributes to crop productivity.

Herbicides, quantity of seeds, and manure are negatively influencing the productivity for the adopters, implying that CSA technologies are crucial for improvement of productivity. On the count of agricultural inputs, one cannot improve productivity in isolation of CSA. An insight from findings is that CSA technologies improve crop productivity, and herbicides are not appropriate for soil conditions, and large family decreases productivity as in the work of Akter et a. (2022).

Total chemical fertilizers are positively related to productivity for non-adopters implying that farmers who did not adopt CSA technologies, chemical fertilizers were important to them, as they do not use CSA technologies in their farming. Fertilizers improved soil quality and fertility which eventually improved crop productivity. The same result was obtained that chemical fertilizers are crucial for soil nutrients that improved crop productivity (Lamanna et al., 2016).

Gender is an important determinant of crop productivity. Being a male increased the probability of being productive, as agriculture requires physical fitness and resources to adopt CSA. The same findings were obtained by Teklewold et al. (2020) in Tanzania.

Age is negative and statistically significant contributes to the productivity of non-adopters. It may imply that non-adopters become less active in adopting new farming technologies, also less active physically that decline in crop productivity. With this regard, elders are less productive compared to other age groups (Akter et al., 2022).

Also, female adults are negatively and statistically related to crop productivity for non-adopters implying that involving in agriculture without CSA adoption reduce productivity. CSA technologies, if complemented with other production inputs such as physical fitness, may augment crop productivity.

Distance to the market and home are positively and statistically significant influencing crop productivity for non-adopters. The market is a place for the acquisition of knowledge, advice, inputs, and other social benefits that improve crop productivity. These findings are in light of the finding by (Akter et al., 2022) who find that market and physical characteristics greatly influence crop productivity.

4.2. Crop productivity impact of CSA

On count, the productivity effect indicates that smallholder farmers benefit from CSA adoption. In Table 3, the third and fourth columns present the factual and counterfactual for both regime functions, respectively. The first row has aggregate crop productivity in factual mean from regime one function, which is 2873.614 kg, but their counterfactual mean is 2835.665 kg. The difference, which is the ATT, shows an increase of 1.34% in productivity.

Referring to the second row where, the factual for non-adopters is 1226.304 kg but if had they adopted their productivity would be 1393.722 kg giving an ATU of 13.65%. The findings reveal that the ATT is positively consistent with the findings of Amadu et al. (2020a) in Malawi and

Akter et al. (2022) in Bangladesh. Furthermore, crops indicate that adopters on average gain relatively more than non-adopters. However, adopters gain more in beans for 86.6% for factual compared to their counterfactual.

Table 3. Productivity effects

Grain Type	Effect	CSA technologies		Diff (SE)	%Change
		Mean (Adopters)	Mean(non-adopter)		
Aggregated Productivity (Kg)	ATT	2873.614	2835.665	37.949***(11.143)	1.34
	ATU	1393.722	1226.304	167.418***(10.407)	13.65
Maize (Kg)	ATT	2286.052	2158.344	127.708***(16.861)	5.92
	ATU	1252.439	1053.703	198.736***(11.737)	18.86
Paddy (Kg)	ATT	2710.396	2525.928	184.468***(24.929)	7.30
	ATU	1639.13	1233.064	406.066***(26.181)	32.93
Beans (Kg)	ATT	702.129	374.272	327.857***(37.281)	86.60
	ATU	381.028	370.98	10.048***(13.895)	2.71

*, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.
Source: NCSA of Tanzania 2020

4.3. ESR for Income

The regression results for the first and second stages are presented in Table 4. From the first stage, we reveal that the cost of input, gender, distance to the market and home, education, and off-income residual are negatively and statistically significantly related to CSA adoption. Distance to the market and home in Table 2 is consistent with the results in Table 4 and its discussion already done.

Table 4. ESR results for income

First stage estimation of ESR.		Second stage estimation of ESR.	
Variables	Coef. estimates (standard errors)	Adopters Coef. estimates (standard	Non-adopters Coef. estimates (standard

		errors)	errors)
Constant	-4.313(0.458)	12.904***(0.178)	12.945***(0.243)
Agricultural Inputs			
GrandCostsMPB	-1.67e-06***(5.01e-07)	3.08e-06***(2.24e-07)	3.95e-06 *** (4.78e-07)
LnTotlQtyFertilizerMPB	0.198***(0.023)	-0.018(0.014)	0.023(0.025)
LnLandSize	0.258***(0.044)	0.196***(0.029)	0.180***(0.049)
Socioeconomics			
gender	-0.146*(0.081)	0.170***(0.058)	0.236***(0.085)
age	0.029***(0.004)	-0.005***(0.002)	-0.007***(0.002)
LnNumber_male	0.017(0.056)	0.075*(0.044)	-0.017(0.069)
LnNumber_female	0.042(0.054)	0.043(0.042)	0.187***(0.066)
lnHhSize	0.083***(0.032)	-0.035(0.025)	0.028(0.038)
Off_Fmincome	6.979***(0.773)	-0.046(0.050)	0.059(0.078)
lntotal_Lvstok	0.057(0.071)	0.037(0.052)	0.143(0.094)
Access status			
LnDstnce_Markt	-0.061**(0.028)	-0.016(0.023)	-0.002(0.034)
LnDstnce_Road	0.098**(0.038)	-0.041(0.030)	-0.078**(0.041)
Institutional			
Crdit_accss	0.256*(0.150)	-0.022(0.106)	0.078(0.200)
Biophysical status			
LnDstnce_Home	-0.015***(0.005)	-0.001(0.003)	0.013**(0.005)
IVs			
Years_Educ	-0.060***(0.016)		
Off_fmincomeResdl	-6.921***(0.774)		
Statistical diagnostics			
LR test of indep. eqns.: chi2(1)	43.51		
Prob > chi2	0.0000		
Log likelihood	-3380.5912		
sigma_1		0.777***(0.033)	
sigma_2			1.214***(0.050)
rho_1		0.683***(0.065)	
rho_2			0.751***(0.047)
N	1860	1860	1860

*, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

Source: NCSA of Tanzania 2020

4.4. Income impact of CSA

The results from the second stage of ESR are reported in Table 4. The determinants of smallholder farmers income of regimes one and two are summarized in third and fourth columns, respectively. Factors such as land size and gender (being a man) are crucial as they increase income.

More land may increase income. Also, being a man is related to high income due to the advantages of physical fitness and resources they possess. Farmers with more land can cultivate and rent the land to other farmers, which increases income. The findings are consistent with the findings of Akter et al. (2022) in Bangladesh.

For adopters of CSA technologies, land size, costs of input, age, and number of male adults are crucial determinants of income, while for non-adopters' factors such as distance to the market and home, number of female adults, influence their income.

The differences in the determinant justify the use of the ESR. Interestingly, age reduces the productivity and income of the household, implying that a unit increase in age reduces the income of the household because of usual farming habits under experience. The higher the age, the less the ability to produce or generate income; the elderly are less energetic, low in the acquisition of new farming knowledge or technologies that make them unproductive compared to the young. The findings are in line with the findings of Noltze et al. (2013) in Timor Leste.

Considering the ATT and ATU of the income effect of CSA presented in Table 5. The results reveal that the impact of CSA technologies is varied. For aggregate crops' income, the factual increased income by about 8.31%, whereas the counterfactual (had they adopted CSA), they would obtain an income increase of 13.55%. Interestingly, for individual crops, CSA adopters gain income on average relatively more than their counterfactual and adopter of CSA for beans gets more income for about 14.31% followed by maize gain of 8.74%.

The result suggests that ATU for non-adopters would gain more income if they had adopted. For instance, non-adopters if had they adopted maize would have increased income by 13.81%. The findings are consistent with other findings in Amadu et al. (2020) in Malawi, in Belay et al. (2022) in Ethiopia, and Noltze et al. (2013) in Timor Leste

Table 5. Income effects

Grain Type	Effect	CSA technologies		Diff (SE)	%Change
		Mean (Adopters)	Mean (non-adopter		
Total Income	ATT	13.542	12.503	1.039***(.017)	8.31
	ATU	14.384	12.667	1.717***(.022)	13.55
Maize	ATT	12.949	11.908	1.041***(.0248)	8.74
Income	ATU	13.763	12.093	1.670***(.029)	13.81
Paddy	ATT	13.609	13.438	.171***(.04)	1.27
Income	ATU	12.999	12.775	.224***(.044)	1.75
Beans	ATT	14.226	12.445	1.781***(.098)	14.31
Income	ATU	15.086	13.782	1.304***(.087)	9.46

*, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

Source: NCSA of Tanzania 2020

4.5. Robustness check

To validate PSM results, we compared the results of matching before matching, which is crucial (see Figure 2) for both income and productivity models. It is important to make sure that the observable statuses are comparable and bias is reduced (Caliendo & Kopeinig, 2008).

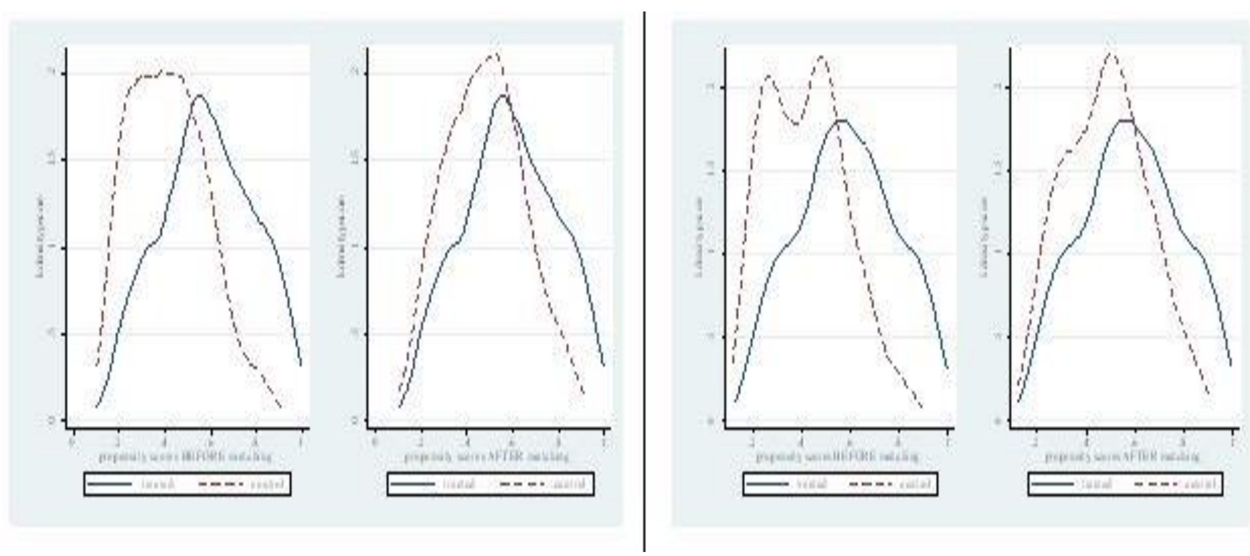

Figure 2. Before and after matching both productivity and income

Source: NCSA of Tanzania 2020

As part of the robustness check we find consistent results for both productivity and income models using PSM in Table 6.

Table 6. PSM results for Productivity and Income effects

Effect	Variable Sample	Treated	Controls	Difference	SE	T-Stat.
Productivity	Grain productivity Unmatched	2873.616	1226.309	1647.307***	40.108	41.07
	ATT	2873.616	1333.52	1540.096***	78.615	19.59
Income	Household Income Unmatched	13.535	12.679	.856***	.043	19.81
	ATT	13.535	13.066	.469***	.109	4.32

*, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

Source: NCSA of Tanzania 2020

4.6. Limitations of the study

We applied a robust identification strategy, and we present crucial results. However, the study faces some limitations. The major limitation may emanate from the type of data. We employed cross-section data, which fails to capture the time-variant effects, such as weather data.

5. Conclusion and policy implications

The study examines the determinants of CSA adoption and its impacts on farm performance and income. We controlled for any thought biases that might have affected the estimates, such as endogenous variables and selection.

The results on the determinants reveal that land size, education, chemical fertilizers, adult females, credit access, off-farm income, and distance to the market and farm are crucial for explaining the CSA adoption, crop productivity, and income. To have a sustainable scale up of the CSA technologies integration in agriculture, the findings enlighten that stakeholders should promote through campaigns, workshops, education provision through extension officers, credit provision, and friendly acquisition procedures of farming land.

Further, the results indicate that conscious adoption of CSA technologies impacts crop production and income. Non-adopters, if had they adopted, would significantly increase their productivity and income.

The government, in collaboration with other development partners and other stakeholders of agricultural transformation, can reinforce adoption of CSA technologies based on the evidence in this study and other studies that CSA adoption improves farm performance and income.

Generally, the results on determinants and effects of CSA adoption have both policy and academic implications. First, the findings help in answering the question of how we can scale up the use of CSA to be able to achieve production, adaptation, and mitigation. Second, the effects of CSA adoption on crop productivity and income help to answer questions on how we can boost productivity and income for food security and poverty reduction, eventually increasing farmers resilience in adverse climatic conditions. Lastly, the study adds knowledge to the extant literature about determinants and the impact of CSA adoption on farm performance and income.

6. **Declarations**

Author contribution statement

Yohane Kitwima Magembe: Comprehended and designed the study; analyzed and interpreted the data, materials, analysis tools, and writing the paper. Martin Bai: Proofreading, editing, grammar, and setup.

Funding statement

No funding is received for this work.

Ethical declaration

This paper uses secondary data. At the time of data collection, clearance and permission from relevant authorities and informed consent from respondents were seriously adhered to.

Data availability statement

Data is available from NBS as NSCA 2019/20 with Ref. TZA-NBS-NSCA-2019-v01. The data can be downloaded from [https://www.nbs.go.tz/tnada]. Downloaded on 20/05/2023.

Competing Interest

We declare no known competing interests.

Additional information

No extra information is available for this paper.

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References

Abdulai, A., & Huffman, W. (2014). *The Adoption and Impact of Soil and Water Conservation Technology : An Endogenous Switching Regression Application*.

Abdulai, A. N. (2016). Impact of conservation agriculture technology on household welfare in Zambia. *Agricultural Economics (United Kingdom)*, *47*(6), 729–741. https://doi.org/10.1111/agec.12269

Acclassato, D., Goudjo, G. G., & Senou, M. M. (2021). Access to finance and difference in family farm productivity in Benin: Evidence from small farms. *Scientific African*, *13*, e00940. https://doi.org/10.1016/j.sciaf.2021.e00940

Akter, A., Geng, X., Endelani, G., Lu, H., Hoque, F., Kiraru, M., & Abbas, Q. (2022). Climate Risk Management Income and yield effects of climate-smart agriculture (CSA) adoption in flood prone areas of Bangladesh : Farm level evidence. *Climate Risk Management*, *37*, 100455. https://doi.org/10.1016/j.crm.2022.100455

Ali, A., & Erenstein, O. (2017). Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. *Climate Risk Management*, *16*, 183–194. https://doi.org/10.1016/j.crm.2016.12.001

Amadu, F. O., Mcnamara, P. E., & Miller, D. C. (2020). Understanding the adoption of climate-smart agriculture : A farm-level typology with empirical evidence from southern Malawi. *World Development*, *126*, 104692. https://doi.org/10.1016/j.worlddev.2019.104692

Amadu, F. O., McNamara, P. E., & Miller, D. C. (2020). Yield effects of climate-smart agriculture aid investment in southern Malawi. *Food Policy*, *92*(January 2019), 101869. https://doi.org/10.1016/j.foodpol.2020.101869

Autio, A., Johansson, T., Motaroki, L., Minoia, P., & Pellikka, P. (2021). Constraints for adopting climate-smart agricultural practices among smallholder farmers in Southeast Kenya. *Agricultural Systems*, *194*(January), 103284. https://doi.org/10.1016/j.agsy.2021.103284

Balew, S., Agwata, J., & Anyango, S. (2014). *Determinants of Adoption Choices of Climate Change Adaptation Strategies in Crop Production by Small Scale Farmers in Some Regions of Central Ethiopia*. *4*(4).

Belay, M., Bekele, G., & Ibrahim, M. (2022). Heliyon Measuring the poverty reduction effects of adopting agricultural technologies in rural Ethiopia : fi ndings from an endogenous switching regression approach. *Heliyon*, *8*(November 2021), e09495. https://doi.org/10.1016/j.heliyon.2022.e09495

Berger, T., Troost, C., Wossen, T., Latynskiy, E., Tesfaye, K., & Gbegbelegbe, S. (2017). Can smallholder farmers adapt to climate variability, and how effective are policy interventions? Agent-based simulation results for Ethiopia. *Agricultural Economics (United Kingdom)*, *48*(6), 693–706. https://doi.org/10.1111/agec.12367

Bhatnagar, S., Chaudhary, R., Sharma, S., Janjhua, Y., Thakur, P., Sharma, P., & Keprate, A. (2024). Environmental and Sustainability Indicators Exploring the dynamics of climate-smart agricultural practices for sustainable resilience in a changing climate. *Environmental and Sustainability Indicators*, *24*(May), 100535. https://doi.org/10.1016/j.indic.2024.100535

Bongole, A. (2023). Adoption of Multiple Climate Smart Agricultural Practices in Mbeya and Songwe Regions in Tanzania. *Journal of African Economic Perspectives*, *1*(1), 41–60. https://doi.org/10.58548/2023jaep11.4160

Bongole, A. J. (2022a). *AJER, Volume 10 (2), March 2022, A.J., Bongole Welfare Effects of Farming Household' Usage of Combination of Climate Smart Agriculture Practises in the Southern Highlands of Tanzania. Abiud J. Bongole †* (Vol. 10, Issue March).

Bongole, A. J. (2022b). Welfare Effects of Farming Household' Usage of Combination of Climate Smart Agriculture Practises in the Southern Highlands of Tanzania. *Ajer*, *10*(2), 88–100.

Bongole, A. J., Hella, J., Kikuu, C., Resource, N., & Kikuu, C. (2020). *Usage of Climate Smart Agriculture Practices: An Analysis of Farm Households' Decisions in Southern Highlands of Tanzania 1*. *19*(2), 238–255.

Bongole, A. J., Hella, J. P., & Bengesi, K. M. K. (2022). Combining Climate Smart Agriculture Practises Pays Off: Evidence on Food Security From Southern Highland Zone of Tanzania. *Frontiers in Sustainable Food Systems*, *6*(April), 1–17. https://doi.org/10.3389/fsufs.2022.541798

Bouteska, A., Sharif, T., Bhuiyan, F., & Zoynul, M. (2024). Impacts of the changing climate on agricultural productivity and food security : Evidence from Ethiopia. *Journal of Cleaner Production*, *449*(May 2023), 141793. https://doi.org/10.1016/j.jclepro.2024.141793

Caliendo, M., & Kopeinig, S. (2008). Some practical guidance for the implementation of propensity score matching. *Journal of Economic Surveys*, *22*(1), 31–72.

Coderoni, S., & Pagliacci, F. (2023). The impact of climate change on land productivity. A micro-level assessment for Italian farms. *Agricultural Systems*, *205*(October 2022), 103565. https://doi.org/10.1016/j.agsy.2022.103565

Coulibaly, J. Y., Chiputwa, B., Nakelse, T., & Kundhlande, G. (2017). Adoption of agroforestry and the impact on household food security among farmers in Malawi. *Agricultural Systems*, *155*(March 2016), 52–69. https://doi.org/10.1016/j.agsy.2017.03.017

Craparo, A. C. W., Van Asten, P. J. A., Läderach, P., Jassogne, L. T. P., & Grab, S. W. (2015). Coffea arabica yields decline in Tanzania due to climate change: Global implications. *Agricultural and Forest Meteorology*, *207*, 1–10. https://doi.org/10.1016/j.agrformet.2015.03.005

Daum, T., Ygu, P., Adegbola, C., Daudu, C., Issa, F., Kamau, G., Oumar, A., Mose, L., Ndirpaya, Y., Fatunbi, O., Zossou, R., Kirui, O., & Birner, R. (2022). *Mechanization , digitalization , and rural youth - Stakeholder perceptions on three mega-topics for agricultural transformation in four African countries*. *32*. https://doi.org/10.1016/j.gfs.2022.100616

Dercon, S., & Christiaensen, L. (2011). Consumption risk, technology adoption and poverty traps: Evidence from Ethiopia. *Journal of Development Economics*, *96*(2), 159–173. https://doi.org/10.1016/j.jdeveco.2010.08.003

Elizabeth, H., Mary, S., Whitfield, S., Gaworek-michalczenia, M. F., Walker, J., Joseph, G., & Mziray, S. (2021). Innovation systems and affordances in climate smart agriculture. *Journal of Rural Studies*, *87*(January), 199–212. https://doi.org/10.1016/j.jrurstud.2021.09.001

Erekalo, K. T., Pedersen, S. M., Christensen, T., Denver, S., Gemtou, M., Fountas, S., & Isakhanya, G. (2024). Review on the contribution of farming practices and technologies towards climate-smart agricultural outcomes in a European context. *Smart Agricultural Technology*, *7*(December 2023), 100413. https://doi.org/10.1016/j.atech.2024.100413

FAO, IFAD, UNICEF, W. and W. (2024). *The State of Food Security and Nutrition in the World 2024 – Financing to end hunger, food insecurity and malnutrition in all its forms. Rome. https://doi.org/10.4060/cd1254en The* (p. 286).

FAO. (2010). The State of Food Insecurity in the World Addressing food insecurity in protracted crises 2010 Key messages. In *Notes*.

FAO. (2013). *FAO. 2013. Climate smart agriculture sourcebook. Rome: Food and Agriculture Organisation.* (pp. 1–263). https://doi.org/10.3726/b11522

FAO. (2015). *The economic lives of smallholder farmers* (p. 48).

FAO. (2017a). *The future of food and agriculture Trends and challenges* (p. 180).

FAO. (2017b). The impact of disasters and crises on agriculture and food security. In *Food and Agriculture Organization*.

FAO. (2019). *The State of Food Security and Nutrition in the World 2019. Safeguarding against economic slowdowns and downturns. Rome, FAO. Licence: CC BY-NC-SA 3.0 IGO.* (p. 320).

Farrell, M. J. (1957). The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society.*, *120*(3), 253–290.

Feng, X., Sun, T., Guo, J., Cai, H., Qian, C., Hao, Y., Yu, Y., Deng, A., Song, Z., & Zhang, W. (2023). Climate-smart agriculture practice promotes sustainable maize production in northeastern China: Higher grain yield while less carbon footprint. *Field Crops Research*, *302*(April), 109108. https://doi.org/10.1016/j.fcr.2023.109108

Forsund, F. R., Lovell, C.A. K., & P. S. (1980). A survey of frontier production functions and of their relationship to efficiency measurement. *Journal of Econometrics*, *13*(1), 5–25.

Fuglie, K. O., & Bosch, D. J. (1995). *Economic and Environmental Implications of Soil Nitrogen Testing : A Switching-Regression Analysis*. *77*(November), 891–900.

Greene, W. H. (2003). *Econometric analysis, Fifth Edition*.

Gwambene, B., Liwenga, E., & Mung'ong'o, C. (2023). Climate Change and Variability Impacts on Agricultural Production and Food Security for the Smallholder Farmers in Rungwe, Tanzania. *Environmental Management*, *71*(1), 3–14. https://doi.org/10.1007/s00267-022-01628-5

Habtewold, T. M. (2021). Impact of climate-smart agricultural technology on multidimensional poverty in rural Ethiopia. *Journal of Integrative Agriculture*, *20*(4), 1021–1041. https://doi.org/10.1016/S2095-3119(21)63637-7

Heckman, J. J. (2001). Econometrics and empirical economics. *Journal of Econometrics*, *100*(1), 3–5. https://doi.org/10.1016/S0304-4076(00)00044-0

Heckman, J. J. (2013). Sample selection bias as a specification error. *Applied Econometrics*, *31*(3), 129–137. https://doi.org/10.2307/1912352

Hellin, J., & Fisher, E. (2018). Development in Practice Building pathways out of poverty through climate smart agriculture and effective targeting agriculture and e ff ective targeting. *Development in Practice*, *28*(7), 1–6. https://doi.org/10.1080/09614524.2018.1492516

Huang, H., von Lampe, M., & van Tongeren, F. (2011). Climate change and trade in agriculture. *Food Policy*, *36*(SUPPL. 1), S9–S13. https://doi.org/10.1016/j.foodpol.2010.10.008

Hussain, M., Butt, A. R., Uzma, F., Ahmed, R., Irshad, S., Rehman, A., & Yousaf, B. (2020). A comprehensive review of climate change impacts, adaptation, and mitigation on environmental and natural calamities in Pakistan. *Environmental Monitoring and Assessment*, *192*(1). https://doi.org/10.1007/s10661-019-7956-4

Irish Aid. (2011). *Accountable to People, Accounting for Aid. Available online at: https://www.irishaid.ie/media/irishaid/allwebsitemedia/ 20newsandpublications/publicationpdfsenglish/2011-irish-aid-annual- report.pdf (Retrivied 14/12/ 2024).*

Islam, T., & Nursey-bray, M. (2017). Adaptation to climate change in agriculture in Bangladesh : The role of formal institutions. *Journal of Environmental Management*, *200*, 347–358. https://doi.org/10.1016/j.jenvman.2017.05.092

Issahaku, G., & Abdulai, A. (2019). *Can Farm Households Improve Food and Nutrition Security through Adoption of Climate-smart Practices ? Empirical Evidence from Northern Ghana*. *0*(0), 1–22. https://doi.org/10.1093/aepp/ppz002

Jena, P. R., Tanti, P. C., & Maharjan, K. L. (2023). Determinants of adoption of climate resilient practices and their impact on yield and household income. *Journal of Agriculture and Food Research*, *14*(June), 100659. https://doi.org/10.1016/j.jafr.2023.100659

Jon Hellin and Eleanor Fisher. (2019). Climate-Smart Agriculture and Non-Agricultural Livelihood Transformation. *Climate*, 1–8.

Jones, K., Nowak, A., Berglund, E., Grinnell, W., Temu, E., Paul, B., Renwick, L. L. R., Steward, P., Rosenstock, T. S., & Kimaro, A. A. (2023). Evidence supports the potential for climate-smart agriculture in Tanzania. *Global Food Security*, *36*(December 2021), 100666. https://doi.org/10.1016/j.gfs.2022.100666

Khatri-chhetri, A., Aggarwal, P. K., Joshi, P. K., & Vyas, S. (2016). Farmers ' prioritization of climate-smart agriculture (CSA) technologies. *AGSY*. https://doi.org/10.1016/j.agsy.2016.10.005

Kifle, T., Yayeh, D., & Mulugeta, M. (2022). Factors influencing farmers adoption of climate smart agriculture to respond climate variability in Siyadebrina Wayu District , Central highland of Ethiopia. *Climate Services*, *26*(December 2020), 100290. https://doi.org/10.1016/j.cliser.2022.100290

Kimaro, A. A., Mpanda, M., Rioux, J., Aynekulu, E., Shaba, S., Thiong, M., Abwanda, S., Shepherd, K., Neufeldt, H., & Rosenstock, T. S. (2015). Is conservation agriculture ' climate-smart ' for maize farmers in the highlands of Tanzania ? *Nutrient Cycling in Agroecosystems*. https://doi.org/10.1007/s10705-015-9711-8

Kurgat, B. K., Lamanna, C., Kimaro, A., Namoi, N., Manda, L., & Rosenstock, T. S. (2020). *Adoption of Climate-Smart Agriculture Technologies in Tanzania*. *4*(May). https://doi.org/10.3389/fsufs.2020.00055

Lamanna et al., 2016. (2016). *Lamanna, C, Namoi N, Kimaro A, Mpanda M, Egeru A, Okia C, Ramirez-Villegas J, Mwongera C, Ampaire E, van Asten P, Winowiecki L, Läderach P, Rosenstock TS. (2016). Evidence-based opportunities for out-scaling climate-smart agriculture in East Africa. CCAFS. October*, 56–59.

https://doi.org/10.13140/RG.2.2.14846.79683

Lee, L. (1982). *Some Approaches to the Correction of Selectivity Bias. Oxford University Press. The Review of Economic Studies, Vol. 49, No. 3 (Jul., 1982), pp. 355-372*. *49*(3), 355–372.

Li, Y., Li, Z., Cui, S., Jagadamma, S., & Zhang, Q. (2019). Residue retention and minimum tillage improve physical environment of the soil in croplands: A global meta-analysis. *Soil and Tillage Research*, *194*(January), 104292. https://doi.org/10.1016/j.still.2019.06.009

Lipper, L &Zilberman, D. (2018). *A short history of the evolution of the climate smart agriculture approach and its links to climate change and sustainable agriculture debates. In Climate Smart Agriculture (pp. 13-30). Springer, Cham.* (Vol. 52). https://doi.org/10.1007/978-3-319-61194-5_13

Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck, A., Neufeldt, H., Remington, T., … Torquebiau, E. F. (2014). Climate-smart agriculture for food security. *Nature Climate Change*, *4*(12), 1068–1072. https://doi.org/10.1038/nclimate2437

Lovell, C. A. K. (1993). The measurement of productive efficiency: techniques and applications. In *Oxford University Press, Oxford* (pp. 1–21).

Ma, W., Renwick, A., & Bicknell, K. (2018). *Higher Intensity , Higher Profit ? Empirical Evidence from Dairy Farming in New Zealand*. https://doi.org/10.1111/j.1467-6419.2007.00503.x

Maddala, G. S. (1986). *Limited-dependent and qualitative variables in Econometrics. The University of Cambridge Press 1986, New York, USA* (A. D. D. M. H. Sonnenschein (ed.)).

Marenya, P. P., Kassie, M., Jaleta, M., Rahut, D. B., & Erenstein, O. (2017). *Predicting minimum tillage adoption among smallholder farmers using micro- level and policy variables*. 1–22. https://doi.org/10.1186/s40100-017-0081-1

Mirzabaev, A., Bezner Kerr, R., Hasegawa, T., Pradhan, P., Wreford, A., Cristina Tirado von der Pahlen, M., & Gurney-Smith, H. (2023). Severe climate change risks to food security and nutrition. *Climate Risk Management*, *39*(June 2022), 100473. https://doi.org/10.1016/j.crm.2022.100473

Missiame, A., Nyikal, R. A., & Irungu, P. (2021). What is the impact of rural bank credit access on the technical efficiency of smallholder cassava farmers in Ghana? An endogenous switching regression analysis. *Heliyon*, *7*(5), e07102. https://doi.org/10.1016/j.heliyon.2021.e07102

Mrema, J. D., Nyaruhucha, C. N., & Mwanri, A. W. (2023). Human Nutrition & Metabolism Dietary intake and diversity among children of age 6 – 59 months in lowland and highland areas in Kilosa District in Morogoro , Tanzania. *Human Nutrition & Metabolism*, *33*(September 2022), 200205. https://doi.org/10.1016/j.hnm.2023.200205

Mugabe, P. A. (2020). Assessment of Information on Successful Climate-Smart Agricultural Practices/ Innovations in Tanzania. *Handbook of Climate Change Resilience, Volume 1-4*, *4*, 2721–2741. https://doi.org/10.1007/978-3-319-93336-8_180

Mukasa, A. N., Simpasa, A. M., & A. O. S. (2017). *Credit constraints and farm productivity: Micro-level evidence from smallholder farmers in Ethiopia. Working Paper Series No. 247. African Development Bank Group* (Issue 247, pp. 1–40).

Murray, U., Gebremedhin, Z., Brychkova, G., & Spillane, C. (2016). *Smallholder Farmers and Climate Smart Agriculture : Technology and Constraints amongst Women Smallholders in*

Malawi. https://doi.org/10.1177/0971852416640639

Musa, C. M., Kiboi, M., Macharia, J., Ng, O. K., Kosgei, D. K., Mulianga, B., Okoti, M., & Ngetich, F. K. (2022). *Heliyon Adoption of climate-smart agricultural practices among smallholder farmers in Western Kenya : do socioeconomic , institutional , and biophysical factors matter ? 8*(November 2021). https://doi.org/10.1016/j.heliyon.2021.e08677

Mutungi, C., Tungu, J., Amri, J., Gaspar, A., & Abass, A. (2022). Nutritional benefits of improved post-harvest handling practices for maize and common beans in Northern Tanzania : A quantitative farm-level assessment. *Journal of Stored Products Research*, *95*(December 2021), 101918. https://doi.org/10.1016/j.jspr.2021.101918

Mwalupaso, G. E., Wang, S., Eshetie, A. M., & Tian, X. (2020). *Ameliorating Food and Nutrition Security in Farm Households : Does Informatization Matter ?* 1–20.

Mwongera, C., Shikuku, K. M., Twyman, J., Läderach, P., Ampaire, E., Van Asten, P., Twomlow, S., & Winowiecki, L. A. (2017). Climate smart agriculture rapid appraisal (CSA-RA): A tool for prioritizing context-specific climate smart agriculture technologies. *Agricultural Systems*, *151*, 192–203. https://doi.org/10.1016/j.agsy.2016.05.009

National Bureau of Statistics. (2020). *National Bureau of Statistics. National Sample Census of Agriculture 2019/20, Public Use File. Ref.TZA-NBS-NSCA-2019-v01. Downloaded from [https://www.nbs.go.tz/tnada] on [26/06/2022].* (pp. 1–7).

Newell, P., Taylor, O., Naess, L. O., Thompson, J., Mahmoud, H., Ndaki, P., Rurangwa, R., & Teshome, A. (2019). Climate Smart Agriculture? Governing the Sustainable Development Goals in Sub-Saharan Africa. *Frontiers in Sustainable Food Systems*, *3*(August), 1–15. https://doi.org/10.3389/fsufs.2019.00055

Ngaiwi, M. E., Molua, E. L., Sonwa, D. J., Meliko, M. O., Bomdzele, E. J., Ayuk, J. E., Castro-Nunez, A., & Latala, M. M. (2023). Do farmers' socioeconomic status determine the adoption of conservation agriculture? An empirical evidence from Eastern and Southern Regions of Cameroon. *Scientific African*, *19*. https://doi.org/10.1016/j.sciaf.2022.e01498

Noltze, M., Schwarze, S., & Qaim, M. (2013). Impacts of natural resource management technologies on agricultural yield and household income: The system of rice intensification in Timor Leste. *Ecological Economics*, *85*, 59–68. https://doi.org/10.1016/j.ecolecon.2012.10.009

Nyasimi, M., Kimeli, P., Sayula, G., Radeny, M., Kinyangi, J., & Mungai, C. (2017). Adoption and dissemination pathways for climate-smart agriculture technologies and practices for climate-resilient livelihoods in Lushoto, Northeast Tanzania. *Climate*, *5*(3), 1–22. https://doi.org/10.3390/cli5030063

Ogada, M. J., Radeny, M., Recha, J., & Dawit, S. (2021). Adoption of complementary climate - smart agricultural technologies : lessons from Lushoto in Tanzania. *Agriculture & Food Security*, 1–10. https://doi.org/10.1186/s40066-021-00321-w

Ogada, M. J., Radeny, M., Recha, J., & Solomon, D. (2020). Adoption of climate-smart agricultural technologies in Lushoto climate-smart villages in north-eastern Tanzania. *CCAFS Working Paper*, *325*.

Pardey, P. G., Beddow, J. M., Hurley, T. M., Beatty, T. K. M., & Eidman, V. R. (2014). A Bounds Analysis of World Food Futures: Global Agriculture Through to 2050. *Australian Journal of Agricultural and Resource Economics*, *58*(4), 571–589. https://doi.org/10.1111/1467-8489.12072

Peter C. Fishburn. (1970). Utility Theory for Decision Making. In *Rcsarch Analysis*

Corporation.
Ramgopaul Roop, Miles Weaver, A. P. F. & M. M. (2023). Innovative Approaches in Smallholder Farming Systems to Implement the Sustainable Development Goals. In *SDGs in the Americas and Caribbean Region* (pp. 1–28).
Rasheed, A., Mwalupaso, G. E., Abbas, Q., & Tian, X. (2020). Women Participation : A Productivity Strategy in Rice Production. *Sustainability*, *12*, *2870*.
Ray, D. K., West, P. C., Clark, M., Gerber, J. S., Prishchepov, A. V., & Chatterjee, S. (2019). Climate change has likely already affected global food production. *PLoS ONE*, *14*(5), 1–18. https://doi.org/10.1371/journal.pone.0217148
Rioux, J., Laval, E., Karttunen, K., & Lwakatare, M. (2017). Climate-Smart Agriculture Guideline for the United Republic of Tanzania : A country – driven response to climate change , food and nutrition insecurity. *Food and Agriculture Organization of the United Nations.*, pp 1-6.
Rodríguez-Barillas, M., Klerkx, L., & Poortvliet, P. M. (2024). What determines the acceptance of Climate Smart Technologies? The influence of farmers' behavioral drivers in connection with the policy environment. *Agricultural Systems*, *213*(November 2023), 103803. https://doi.org/10.1016/j.agsy.2023.103803
Rowhani, P., Lobell, D. B., Linderman, M., & Ramankutty, N. (2011). Climate variability and crop production in Tanzania. *Agricultural and Forest Meteorology*, *151*(4), 449–460. https://doi.org/10.1016/j.agrformet.2010.12.002
Shahzad, M. F., & Abdulai, A. (2020). Adaptation to extreme weather conditions and farm performance in rural Pakistan. *Agricultural Systems*, *180*(February 2019), 102772. https://doi.org/10.1016/j.agsy.2019.102772
Shemsanga, C., Omambia, A. N., & Gu, Y. (2010). The Cost of Climate Change in Tanzania: Impacts and Adaptations. *Journal of American ScienceJournal of American Science*, *6*(63), 182–196.
Siamabele, B. (2021). The significance of soybean production in the face of changing climates in Africa. *Cogent Food and Agriculture*, *7*(1). https://doi.org/10.1080/23311932.2021.1933745
Tambo, J. A., & Wünscher, T. (2018). Building farmers' capacity for innovation generation: Insights from rural Ghana. *Renewable Agriculture and Food Systems*, *33*(2), 116–130. https://doi.org/10.1017/S1742170516000521
Tanzania National Council for Financial Inclusion (TNCFI). (2017). National Financial Education Framework 2016 - 2020 2017 re-print. In *Finance Research Letters* (1st ed., Vol. 8, Issue 2, p. 40). Elsevier Inc. https://doi.org/10.1016/j.jcorpfin.2020.101831
Teklewold, H. (2023). Understanding gender differences on the choices of a portfolio of climate-smart agricultural practices in sub-saharan Africa. *World Development Perspectives*, *29*(September 2022), 100486. https://doi.org/10.1016/j.wdp.2023.100486
Teklewold, H., Adam, R. I., & Marenya, P. (2020). What explains the gender differences in the adoption of multiple maize varieties? Empirical evidence from Uganda and Tanzania. *World Development Perspectives*, *18*(July 2019), 100206. https://doi.org/10.1016/j.wdp.2020.100206
Teklewold, H., Kassie, M., & Shiferaw, B. (2013). Adoption of multiple sustainable agricultural practices in rural Ethiopia. *Journal of Agricultural Economics*, *64*(3), 597–623. https://doi.org/10.1111/1477-9552.12011

The Alliance for a Green Revolution in Africa (AGRA). (2015). *Africa Agriculture Status Report: Youth in Agriculture in Sub-Saharan Africa. Nairobi, Kenya. Issue No. 3* (pp. 1–232).

Tumbo S.D., Mahoo, H.F, Mutabazi, K.D., Kahimba, F.C., & Kadigi, I. (2017). An Assessment of Tanzania ' s Agricultural Production , Climate Change , Agricultural Trade and Food Security. *The Kenya Institute for Public Policy Research and Analysis (KIPPRA). KIPPRA Working Paper No. 22 2017*.

UN. (2015). *Sustainable Development Goals, 11 August 2015, New York* (Issue August, p. 31).

URT. (2013). *National Agriculture Policy - 2013* (Issue October). Ministry of Agriculture Food Security and Cooperatives, Dar es Salaam.

URT. (2014). Tanzania in Figure 2014, National Bureau of Statistics, Ministry of Finance, 2015. Available online at: https:// www.nbs.go.tz/index.php/en/tanzania-in-figures/275-tanzania-in-figures- 2014 (Retrieved on 14/12/2024). In *United Republic of Tanzania* (p. 98). https://www.nbs.go.tz/index.php/en/tanzania-in-figures/275-tanzania-in-figures-2014

URT. (2015). *Tanzania Climate Smart Agriculture Programme.* (pp. 1–82).

URT. (2016). *2014 / 15 Annual Agricultural Sample Survey Report* (p. 72).

URT. (2017). *Agricultural Sector Development Programme Phase II (ASDP II) November, 2017*.

Wekesa, B. M., Ayuya, O. I., & Lagat, J. K. (2018). Effect of climate-smart agricultural practices on household food security in smallholder production systems: Micro-level evidence from Kenya. *Agriculture and Food Security*, *7*(1), 1–14. https://doi.org/10.1186/s40066-018-0230-0

Williams, J., Daily, G., Noble, A., Matthews, N., Gordon, L., Wetterstrand, H., Declerck, F., Shah, M., Steduto, P., Fraiture, C. De, Hatibu, N., Unver, O., Bird, J., & Sibanda, L. (2016). *Sustainable intensification of agriculture for human prosperity and global sustainability*. https://doi.org/10.1007/s13280-016-0793-6

Wim, Meeusen & Julien, van D. B. (1977). Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. *International Economic Review*, *18*(2), 435–444.

Winthrop et al. (2018). Tanzania Country Climate Change Risk Assessment Report. In *Irish Aid, Resilience and Economic Inclusion Team, Policy Unit February,*.

Wooldridge, J. M. W. (2015). *Econometrics*. *November*.

World Bank (WB). (2015). *Ending Poverty and Hunger by 2030.An Agenda for the global food System. Second Edition, May 2015.* (pp. 1–32). The World Bank Group.

World Bank Group. (2024). *Tanzania Country Climate and Development Report. CCDR Series. © Washington, DC: World Bank Group. http://hdl.handle.net/10986/42483 License: CC BY-NC-ND 3.0 IGO.* (Issue November, pp. 1–90).

APPENDIX

Table A. First stage regression controlling for endogeneity in CSA adoption

Variables	CSA adoption Selection/Choice equation				Endogenous Variable: Off-farm Income			
	Model 1: For Productivity		Model 2: For Income		Logit regression associated with Model 1		Logit regression associated with Model 2	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Constant	1094.439	686.533	16.471***	.327	-.658*	.362	-.569*	.328
Agricultural Inputs								
LnLandSize	-75.233	47.415	-.013	.03	.138**	.065	.154**	.063
LnTotlQtyFertilizerMPB	102.21***	26.26	-.14***	.016	.144***	.031	.138***	.031
GrandCostsMPB	.001	.001	6.40e-06***	3.43e-07	4.10e-06***	6.32e-07	4.04e-06***	5.78e-07
Herbicide	-254.573***	88.608			-.159	.132		
lnQnty_seedKg	31.165	43.963			-.022	.069		
Manure	27.4	76.491			.351***	.106		
Socioeconomics								
gender	108.394	92.075	.488***	.057	.454***	.116	.459***	.115
age	3.573	5.939	-.036***	.003	-.009**	.003	-.009**	.003
lnHhSize	-16.125	28.462	-.059***	.022	.048	.052	.055	.052
crop_failre	-8.165	56.332			-.049	.108		
LnNumber_male	-33.928	48.172	.016	.038	.056	.094	.031	.093
LnNumber_female	-10.456	45.958	.084**	.037	.035	.089	.023	.089
Off_Fmincome	1406.843	1234.943	-6.942***	.557				
Access status								
LnDstnce_Markt	-43.864*	24.058	-.01	.019	-.141***	.046	-.133***	.047
LnDstnce_Road			-.17***	.026			-.029	.059
Institutional/Wealth								
Crdit_accss	231.537*	125.011	-.021	.099	.283	.247	.268	.247
lntotal_Lvstok			.043	.048			.099	.118
Biophysical status								
LnDstnce_Home	5.003	4.596	.025***	.003	.01	.007	.011	.007
IVs								
Years_Educ	18.902	21.142	.128***	.011				
Off_fmincomeResdlPctn	-1396.632	1236.173	6.956***	.558	.191*	.105	.211**	.105
Statistical diagnostics								
Pseudo r-squared					0.106		0.101	
Chi-square					272.883		259.437	
Prob > chi2					0.000		0.000	
N	1857		1860		1857		1860	

*, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

Source: NCSA of Tanzania 2020

Chapter 3

Youth involvement in agricultural activities

Chapter 3 consists of two research papers. The first paper is entitled *"Drivers of Youth Intensity of Participation in Agriculture: Insights from Tanzania."* The paper is submitted for review. The paper investigates the critical challenges and problems facing youth involved in agricultural activities. Further, the paper examines the factors influencing the intensity of participation in agriculture using nationally representative data from the National Sample Census of Agriculture (NSCA) 2020. Descriptive analysis presents the critical problems and challenges that youth are facing in the sector. Using an ordered logit model, the results reveal that social, economic, institutional, demographic, and environmental factors positively influence youth intensity participation. The robustness was done by checking the assumptions of the ordered logistic model, such as independence, linearity, and perfect collinearity. The second paper is entitled *"Youth Higher Intensity, Higher Gains? Empirical Evidence from Crop Farming in Tanzania."* The paper is at the end of the first paper. The paper focuses on the effects of youths' intensity engagement in agriculture on crop farming performance.

Drivers of Youth Intensity of Participation in Agriculture: Insights from Tanzania

Abstract

Attracting and retaining youth in the agricultural sector is a global challenge. The youth unemployment crisis is exacerbating, particularly in the Global South. The impact includes threats to social cohesion, political stability, food security, and poverty reduction. Despite the initiative and research aimed at promoting youth involvement in agriculture, participation has remained low due to negative perceptions about the sector and potential earnings. This study examines the problems and challenges of the sector and the factors driving full-time participation of youth in agriculture using data from the National Sample Census of Agriculture (NSCA) of 2020 in Tanzania. We adopted a descriptive and ordered logit model. Results from descriptive analysis show that unreliable rain associated with floods, pests and diseases, and drought are critical problems, whereas low market prices, too far markets, high transport costs, lack of market information, and insufficient production are major challenges affecting youth in the sector. The results from the ordered logit model reveal that access to land, extension, credit, irrigation, farm tools, agroprocessing, information source channels, profits, membership in farmers' cooperatives and organizations, and distance drive to youth full-time engagement. Surprisingly, education and having off-farm income-generating jobs do not drive full-time employment in the sector. The findings suggest policy measures and academic and elders' interventions to promote the full-time engagement of many youths in the sector as a response to potentially increasing youth unemployment and the associated impacts.

Key Words: Tanzania ordered logit model, youth involvement, unemployment, agricultural activities.

1. Introduction

Youth participation in agricultural activities is a mega topic today that is increasingly drawing the attention of stakeholders (authorities, policymakers, and academia). Participation in agricultural activities functions as a vital means of fuelling individual income and inclusive economic growth in the evolving environment (Akrong & Hundie, 2022; Njeru, 2017; Schumpeter, 1934). For instance, agripreneurship acts as an effective means of driving economic reform, reducing the wealth gap, and creating jobs (Bosma et al., 2021; Parker, 2018).

The sector provides direct benefits to participants and potential for livelihood and economic growth. For instance, agriculture employs 70% of Africans (Ninson & Brobbey, 2023). Further, agriculture accelerates economic growth for 30% of GDP, poverty reduction, food security, a source of raw materials for industries, exportation, and international trade (Mdege et al., 2022; The Alliance for a Green Revolution in Africa (AGRA), 2015; URT, 2017). The unprecedented global population of nine to ten billion who will rise food demand from 2.5% to 3% by 2050 (Schierhorn, 2016; Williams et al., 2016) that increase the necessity of the sector and youth involvement.

Despite the potentials embedded in the sector, not yet utilized to its full potentials, partly explained by the low youth buy-in in the sector (URT, 2022a). Youths' background and environment nurture the coexistence of positive and negative perceptions that fuels negligence about agricultural activities. The contesting perceptions about agricultural opportunities nurture low youth engagement and leave some in dilemma. Youths who are involved still abandon the sector and seek jobs in other sectors (Daum et al., 2022; Kafle et al., 2019).

Governments in developing economies face a critical challenge of youth unemployment (Miriti, 2020) and underdevelopment for hundreds of millions of young people graduating from schools, tertiary institutions, and universities (The Alliance for a Green Revolution in Africa (AGRA), 2019). The situation is partly due to negligence of agricultural-related activities (Shayo, 2020) and skills mismatch in the labour market (Akrong & Hundie, 2022; Yami et al., 2018). About 11 million African youth join the labour market each year, but few are directly absorbed (The Alliance for a Green Revolution in Africa (AGRA), 2015), generating about 72% unemployed youth in the continent (The MasterCard Foundation, 2017).

Youth intensity of participation in agricultural activities is explained by the prevalent factors in a particular society that nurture perceptions and intentions (Ninson & Brobbey, 2023). Youth can be encouraged or discouraged only if the environment nurtures positivity or negativity towards the sector, respectively (Henning et al., 2022).

The growing research strand about youth participation in agriculture presents two major antagonistic views about low youths' buy-in in agriculture (Magagula & Tsvakirai, 2020).

The first is positive perception and intention to participate in agriculture (Maritim, 2020; Magagula & Tsvakirai, 2020), and the second is negative perception with negligence to engage in agriculture, which overwhelms the former (Heifer International, 2021; Sumberg et al., 2017). The former perception is explained by factors that give positive stimuli to youth about agriculture. The perception is pioneered by scholars who believe that agriculture is profitable (Henning et al., 2022; Kaki et al., 2022; Maritim, 2020; Magagula & Tsvakirai, 2020; Muthomi, 2017; Yami et al., 2018; Zidana et al., 2020), youth involve due to support such as finance and skills training (Blattman & Annan, 2011; Henning et al., 2022; Maritim, 2020; Magagula & Tsvakirai, 2020; Chifupa & Tagwi, 2021), and other people believe that agriculture is the end of last resort for direct and immediate gains (Brooks et al., 2013).

The latter perception is explained by factors in the environment that nurtured by low social status for farmers (Losch, 2016; Njeru, 2017; Sumberg et al., 2017), low profitability associated with high farm inputs costs (August, 2020; Njeru, 2017), no enabling environment (Losch, 2016), lack of access to land and infrastructure (Martinson et al., 2019; Wole-Alo et al., 2016), education not linked to farming (Losch, 2016), low technology use (Henning et al., 2022), belief agriculture is not good job and it is for the poor, and elders (Henning et al., 2022; Brooks et al., 2013; Martinson et al., 2019; Wole-Alo et al., 2016), farming is not modern and not compatible with modern jobs, farming is non-attractive and tedious as it requires much strength (Chifupa & Tagwi, 2021; Wole-Alo et al., 2016), lack of funding/loans/grant/credit facilities (Henning et al., 2022; Magagula & Tsvakirai, 2020; Martinson et al., 2019; Chifupa & Tagwi, 2021; Wole-Alo et al., 2016), lack of skills and capacity building (Blattman & Annan, 2011; Heifer International, 2021; Henning et al., 2022; Mariti2020; Magagula & Tsvakirai, 2020; Mcmullin, 2022; Chifupa & Tagwi, 2021), not meant for the educated (Chifupa & Tagwi, 2021), rare role models (Njeru, 2017), work on family farms without pay (Wuni et al., 2017), parents advise children not to venture into agriculture career (Heifer International, 2021; Mengistu, 2017; Sumberg et al., 2017), low innovations in agriculture, low productivity, policies not well structured to motivate the youth (Heifer International, 2021), agriculture is labour intensive (Yami et al., 2018), weak linkages in the value chain (Janzen, 2014), agricultural incomes are seasonal after harvest and sell the crops (The Allience for a Green Revolution in Africa (AGRA), 2019).

However, the four most notorious factors nurturing youths' negative perceptions and negligence towards agriculture across the African continent are lack of access to information, land, finance, and markets (The Alliance for a Green Revolution in Africa (AGRA), 2019).

The result emanating from negative perceptions is youth abandoning the sector. The impacts of youth Passover in the sector include a dormant agricultural sector, youth unemployment, poverty, and food insecurity in countries whose economies depend on agriculture (URT, 2022). The impacts increase with the population and significantly threaten social cohesion and political stability, such as rebel movement motivation (e.g., in Ethiopia in 2016) and acts of terror (e.g., in Kenya) (The Alliance for a Green Revolution in Africa (AGRA), 2019). Increase in crime rates and substance abuse, urban gangs, political unrest, and increased illegal migration to wealthier nations (World Bank (WB), 2011). The sector has been under the control of elders at an average age of 60 years (Guo et al., 2015) who are economically unstable in terms of power and resource mobilization (FAO, 2014).

However, there are new demands, opportunities, and efforts for agricultural transformation after neglecting the sector since the Structural Adjustment Program in the 1980s (Jayne & Sanchez, 2021). The efforts articulate that youths should be fully involved in agricultural activities as discussed in the Malabo Montpellier Panel in 2018 and in 2019 as one of the large initiatives (Daum et al., 2022).

The Tanzanian government has put in place different initiatives, including state-led initiatives, development partners (DPs), non-governmental organizations (NGOs), companies, and individuals that collaborate with the government to support youth technically and financially (URT, 2022). For instance, the state-led initiatives include the "Building a Better Tomorrow– Youth Initiative for Agribusiness (BBT-YIA) programme" under the Ministry of Agriculture (URT, 2022), funds to empower youth under the Prime Minister's Office, the National Youth Development Policy 2007 (URT, 2007), the National Employment Policy 2008 (URT, 2008), the National Agriculture Policy 2013 (URT, 2013), the Small and Medium Enterprise (SMEs) Development Policy 2002 (URT, 2003), the Kilimo Kwanza (Agriculture First) theme (Yami et al., 2018), and the National Strategy for Youth Involvement in Agriculture (NSYIA) 2016-2021 (URT, 2016).

Despite the interventions, their effectiveness remains unclear (URT, 2022). Sometimes their effects and outreach are localized; many train about horticulture, concentrating in major producing zones, while other youths are left unfacilitated. The initiatives have not yet produced the anticipated flow of youth into the agricultural sector.

Attracting youth is one issue, and retaining them remains a challenge even on a global scale (Mukembo et al., 2014; Veettil et al., 2021). The low youth response to initiatives alerts that there are possibly problems and challenges, and drivers affecting youth involvement in agricultural activities. As a response to this gap, first, the paper investigates the problems and challenges facing youth in the sector. Second, the paper examines the drivers influencing youth intensity of participation in agriculture in Tanzania.

Paper contributions: First, the paper contributes to policy by examining contemporary problems and challenges affecting youth intensity of participation in the agricultural sector. Relevant policies to stimulate interest and make the sector attractive to dynamic youths by addressing the evolving needs.

Second, the paper contributes to the extant literature. We use an ordered logit model to fit the data by modelling the response variable such that youth not participants, part-time participants, and full-time participants. We affiliated several predictors, such as socio-economic, cultural, institutional, and environmental, that influence the identified categories. The methods and findings serve as a basis or reference for future studies in this area.

Lastly, contributes practically to the field by creating awareness among elders and youth about contemporary problems, challenges, and drivers of youth intensity of participation in the sector. Eventually contributing to ending poverty, improving food security and nutrition, and decent work and economic growth.

The rest of the paper is structured as follows: Section 2 reports the literature review and hypotheses development; Section 3 contains materials and methods; Section 4 summarizes the results and discussion; and Section 5 presents the conclusion and policy implications.

2. Literature review and hypotheses development

2.1. Related literature on youth involvement in the agricultural sector

Youth involvement in the agricultural sector and their potential to transform it from merely subsistence to a market-oriented sector has been documented. Several studies in different places that have investigated youth and agriculture in various styles, capacities, and scopes. For instance, studies have examined youth's perceptions and willingness to engage in agricultural activities in South Africa and Nigeria, respectively (Adeyanju et al., 2021; Magagula & Tsvakirai, 2019), whereas youth involvement in agripreneurship and nexus poverty in Kenya (Ouko et al., 2022).

Youth participation in agripreneurship as a function of individual and socio-economic status in Benin (Akrong & Hundie, 2022). In Colombia, Natalia & Stefan (2023) investigated how cooperation, education, and technical support address youth transfer to productive engagement, such as livestock, while in Asia, with evidence from Vietnam (Mulema et al., 2021), investigated barriers and opportunities for the youth engagement in agribusiness. In India, Veettil et al. (2021) examined rural youth gender differences in the participation in the rice value chain.

Kafle et al. (2019) examined the dynamics of youth participation in agriculture in Tanzania and Malawi using panel data, whereas the determinants of youth participation in horticulture agribusiness were examined by Albert et al. (2020). Msangi et al. (2024) investigated how land titling programs promote youth involvement in agriculture, while Shayo (2020) examined secondary school youths' perceptions and choice of agriculture as a career in Tanzania.
To this end, the extant literature on youths' perceptions, interests, and participations in agriculture presents mixed and unclear conclusions using latent endogenous variables. For instance, youths are not attracted to and do not want to engage in agriculture (Wuni et al., 2017), while Yami et al. (2018) hold that youth are interested in agriculture but do not want to be involved in agriculture. They are involved only when other sectors of the economy fail (Kafle et al., 2019). Furthermore, the extant literature is relatively confined on understanding the youths' perceptions and intention to participate using PLS-SEM and the binary logit model. The youth intensity of participation in agricultural activities is rarely discussed in the literature. Several studies focused on how to attract youth to agriculture but not how youth can sustainably involve themselves in agriculture.

The coexistence of these mixed views towards youth participation in agricultural activities warrants further contextual investigation of what observed factors explain youth intensity of participation in agriculture. To embark on extant gaps, first, the paper examines both problems and challenges that hinder youth full-time involvement in the sector. Second, analysed the factors influencing youths' levels of involvement in agriculture. The paper uses a national representative sample of 6419 youth aged between 15 and 35 years from the National Sample Census of Agriculture (NSCA) 2020 in Tanzania.

2.2. Hypotheses development

There is a stream of literature that studies youth involvement and career development in agriculture focusing on youths' perceptions, interests, and attitudes regarding agriculture (Geza et al., 2021). Some studies have investigated youth willingness to participate in agricultural activities as a function of cognitive development from education systems, leaders' aspirations, and programs related to agricultural activities (Albert et al., 2020; Magagula & Tsvakirai, 2020; Shayo, 2020). Other studies have revealed that the environment in which youth live plays a role in youth career decisions and entrepreneurship in agriculture through formal, informal, and non-formal settings (Pindado & Sánchez, 2017; Shayo, 2020).

The past studies heavily rely on the theories such as the Theory of Planned Behaviour (TPB) and Social Cognitive Career Choice (SCCC), Role Model Theory (RMT), Human Capital Theory (HCT), and Psychological Capital Theory (PCT) explaining youth decision-making and behaviour about agriculture (Chipfupa & Tagwi, 2021). These theories form a basis for analysing the endogenous latent variables such as intention, perceived behavioural control, attitude, and subjective norms using the Likert Scale (van Dijk et al., 2016). Based on TPB and SCCC, previous studies have revealed that attitude, perceived behaviour control, and subjective norms explain youth's decision to have a career in (Magagula & Tsvakirai, 2020).

Findings from these theories reveal the heterogeneity factors that influence youth cognition, hence value judgement and decision-making, which alter the propensity to engage in the agricultural sector. Further, meta-analyses, systematic reviews, and case studies have confirmed a low youth buy-in in agriculture (Geza et al., 2021; Magagula & Tsvakirai, 2020; Yami et al., 2018). Less attention is given to exogenous variables such as access and usage of social media that drive intentions to be involved in the agricultural sector (Omulo et al., 2024).

To add to this strand of literature, the current study applies Social Learning Theory (SLT), which proposes that human decision-making behaviour is affected by stimuli from the existing environment in which person can weigh and form bases for decision-making about an event (Esters & Bowen, 2005). The SLT holds that decision-making is affected by the product of some interacting factors bounding youth decision-making regarding opportunities in agriculture. These include socioeconomic status, demographics, and environmental factors (Esters & Bowen, 2005; Krumboltz et al., 1976). For instance, family status influences youth perceptions of agriculture (Arenius & Minniti, 2005). If the stimuli emanating from the community nurture positive attitudes, they will promote youth ventures in agriculture, and vice versa is true (Liñán et al., 2011). The interactions between exogenous factors create knowledge, experience, and awareness through formal, non-formal, and informal settings, which are important for effective decision-making (Magagula & Tsvakirai, 2020; Shayo, 2020). We construct hypotheses **H1** to **H5** to test how the interacting factors, such as youth's backgrounds, environmental, and institutional influences, affect youth intensity of participation in the agricultural sector.

H1: Economical factors influence youth ventures in agricultural activities

As previously explained, these variables are likely to discourage or promote youth engagement in agricultural entrepreneurship (Albert et al., 2020; Mulema et al., 2021). Meta-analysis indicates that the selection of socioeconomic factors is subject to the objectives and data available to the researcher (Geza et al., 2021). In this study, we discussed variables that are important for policy action to build positive stimuli for youth promotion in agriculture. We included the access and use of farm tools such as tractors, land ownership, profits accrued from crop sales, off-farm income, and agro-processing.

H2: Social factors influence youth participation in agricultural activities

The extant strand of research confirms that social factors influence either negative or positive youth perceptions, hence their participation in agriculture (Boye et al., 2024; Nyathi et al., 2022; Mukwedeya & Mudhara, 2024). The variables such as number of children, membership in farmers' cooperatives, and farmers organisations in a community are tested to realise their influences on youth intensity of involvement in the sector.

*H3**:** The institutional factors can influence youth engagement in agricultural entrepreneurship*

The existing literature reveals that institutions and infrastructures are crucial in attracting youth involvement in agriculture (Ninson & Brobbey, 2023). To add to the extant literature, this study examined important variables for institutions and infrastructure transformation in favour of youth involvement in the agricultural sector. We examined access to extension services, use of information source channels, access to agricultural credit, and access to irrigation facilities.

H4: Youth demographics have an impact on youth participation in agriculture

As extensively discussed in the extant literature. Variables such as age, gender, education, marital status, and occupation influence decision-making regarding career development (Asare-Nuamah et al., 2024; Mmbengwa et al., 2021). The literature further shows that these variables may influence youth engagement or abandon agriculture (Bezu & Holden, 2014; Thephavanh et al., 2023). To add to this understanding, we tested how gender, education, and age influence youth intensity of participation in the agricultural sector.

H5: The environment that youth survive in influences involvement in agriculture

Environmental, ecological, and cultural factors are rarely discussed in meta-analysis (Geza et al., 2021; Henning et al., 2022; Kalya Dennis Maritim, 2020; Osabohien et al., 2021; Udemezue, 2019; Wuni et al., 2017; Yami et al., 2018). To add to this strand of literature, we test the influence of distance to the farm and nearest market. Distance plays a significant role in the intensity of participation in the agricultural activities. For instance, long distance discourages youth involvement.

3. Materials and Methods

3.1. Data sources and variables

This study uses secondary cross-sectional data from the Tanzania National Sample Census of Agriculture (NSCA) of 2020. The National Master Sample of NBS and OCGS framework for household-level surveys guided the sampling procedures. The sampling procedures started by identifying rural and urban enumerated areas (EAs), which are the Primary Sampling Units (PSUs) for the 2012 Population and Housing Census frame. It involves sorting the regions and districts before probability proportionate to size (PPS). Then they selected agricultural farming households from EAs for data collection. The probability of a household being involved in providing information depends on the number of households in a particular EA and were randomly selected. Structured tools were admitted during data collection. A total of 33,808 households were sampled across the country. The study collapsed the sample to 6419 youth to meet the national standards that youth is the one whose age range is between 15-35 years old (Msangi et al., 2024; Verick, 2009).

3.2. Econometric models

Youth decisions to involve themselves in agricultural activities are more irregular than systematic and non-compulsory on their own initiatives (Ali et al., 2014; Deininger & Feder, 2009). Youth intensity of participation in the sector can be not, part-time, or full-time participating, which follows the ordered response or ordered logit models (OLM) (Greene, 2012). The ordinal responses of OLM are based on the cumulative probabilities of the dependent (response) variable and the logit of each cumulative probability is a linear function of independent variables, with regression coefficients constant across response categories (Agresti, 2010). In OLM the random error is assumed to be normally distributed with zero mean and constant variance (Greene, 2012). The OLM is derived from a latent-variable model, in the same way as a binary logit model can be analysed. The OLM is used to fit the observed factors influencing youth involvement in agriculture. The hypotheses were tested under the OLM that youth background does not influence youth intensity of participation in agriculture. The ordered logit model is appropriate for ordered responses (Albert et al., 2020; Devkota, 2022). It shows how well responses can be predicted by given covariates, of which some may be quantified. In this paper, we model the OLM such that multiple-ordered response categories of youth intensity of participation in agriculture, such as their status, can be (not employed, part-time employed, or full-time employed) in agriculture. We derived the OLM from the latent variable in the underlying process such that

$$Y^{*} = \kappa^{T}\delta_{i} + \omega \qquad (i)$$

Where, Y^{*} represents an unobserved (latent) variable, κ^{T} is the vector of explanatory (predictor) variables, $\delta_{i}$is a vector of coefficients to be estimated, and ω is an error term assumed to follow a standard logistic distribution.

Further, we cannot observe Y^{*}, we instead can only observe the categories of response, which were coded as 0, 1, 2, ……. m. The response category m is thus observed when the underlying continuous response falls in the j-th interval (Albert et al., 2020) such that

$$Y_{i}^{*} = \begin{cases} 0,\ if\ Y^{*} \leq \eta & \text{(not participate in agriculture)} \\ 1,\ if\ \eta_{0} \leq Y^{*} \leq \eta_{1} & \text{(Part-time participation in agriculture} \\ 2,\ if\ \eta_{1} \leq Y^{*} \leq \eta_{2} & \text{(Full-time participation in agriculture)} \\ N\ if\ \eta_{N} \leq Y^{*} & \end{cases} \qquad (ii)$$

Where, Y_{i}^{*} (i= 0, 1, 2, …., m) is the unobservable threshold parameter that was estimated with the other independent variables, η_{i} represents the standard deviation and N is the number of the categories (three for this study) as an ordered response variable.

Further, if the intercept coefficient is included in the model, Y_{0}^{*} is normalized to zero, so that $N - 1$ additional predictors of vector $\kappa's$ (Greene, 2003; Kaplan & Prato, 2012)

Thus, we can write the OLM as a probability of youth intensity of participation in agriculture. We rewrite eqn. (ii) as appear in eqn. (iii) to level up the intensity of youth involvement in agribusiness as

$$P\ (y_i > m = \frac{\exp(\kappa_i\delta - \emptyset_m)}{1+\exp(\kappa_i\delta-\emptyset_m)}, \quad m = 0,1,\ldots..N-1 \qquad (iii)$$

Where, m represents the ordered response category, κ_i identifies the vector of observed independent variables, δ is a vector of coefficients to be estimated, $\emptyset_m$ represents the threshold points of the ordered model, P shows the probability of youth intensity participation in agriculture, y_i is the dependent variable, and N is the number of categories of the ordered response variables.

We applied maximum likelihood estimation techniques to identify the parameters of the model in an iterative procedure to the log likelihood that fit the model. We interpret the results based on the odds ratios (OR) by exponentiating the ordered logit coefficients by specifying the (OR) option in the command area in Stata Ver. 18.

3.3. Variables

The response variable is youth intensity of participation in agriculture. It is a latent that follows an ordinal measure such that the OLM was modelled as the intensity of participation in agriculture. Let Y_i represents the youth intensity of participation in agriculture such that (Y_0= Not participating, Y_1=Part-time participating, Y_2 =Full-time participating).

Further, the study used the literature review synthesis to affiliate the variables that we used as predictors of the response variable. The variables include economic, social, institutional, demographic, and environmental factors as summarized in Table 1.

Table 1. Variables' descriptive statistics, explanation, and sources

Variable	Obs	Mean	Std. Dev.	Min	Max	Reference
AIIntnsty (0=Not; 1=Part time; Full time employed)	6419	.997	.965	0	2	(Devkota, 2022)(Albert et al., 2020)
DstHom Farm (In Km)	6419	4.894	3.192	1	16	(Daudu et al., 2023)(Maku et al., 2023)
DstFarm Mrkt (In Km)	6419	11.124	10.276	1	34	(Daudu et al.,

						2023)(Maku et al., 2023)
Age (In years)	6419	29.994	3.867	18	35	(Giwu et al., 2024)
Genrl_Eductn (1= Formal education, 0=Otherwise)	6419	.229	.42	0	1	(Maku et al., 2023)(Albert et al., 2020)
NoFormalEdctn (1=Yes 0=Otherwise)	6,419	.151	.358	0	1	(Devkota, 2022)
Gender (0=Female, 1=Males	6419	.866	.34	0	1	(Daudu et al., 2023; Giwu et al., 2024)
AcsesExtSev (0=No, 1=Yes)	6419	.082	.275	0	1	(Daudu et al., 2023; Franzel et al., 2019; Giwu et al., 2024)
Usge InfoChanels (0=No, 1=Yes)	6419	.129	.336	0	1	(Irungu et al., 2015; Ogwu et al., 2023)
AcesAgrCredt (0=No, 1=Yes)	6419	.04	.197	0	1	(Daudu et al., 2023; Giwu et al., 2024)
Prctce Irgatn (0=No, 1=Yes)	6419	.082	.274	0	1	(Devkota, 2022)
Use Tractor (0=No, 1=Yes)	6419	.366	.482	0	1	(Mohammed et al., 2023; Pliakoura & Beligiannis, 2023)
Mmber Coprtive (0=No, 1=Yes)	6419	.037	.188	0	1	(Daudu et al., 2023; Maku et al., 2023)
Mmber FrmOrgztn (0=No, 1=Yes)	6419	.023	.151	0	1	(Giwu et al., 2024)
lnProfts (In TZS)	6419	9.996	5.904	0	19.1	(Devkota, 2022)
Off Fmincome (0=No, 1=Yes)	6419	.566	.496	0	1	(Cheteni et al., 2017; Maku et al., 2023)
AgPrdctProcssng (0=No, 1=Yes)	6419	.125	.331	0	1	(Geza et al., 2023)
LandOwnshp (0=No, 1=Yes)	6419	.758	.428	0	1	(Bezu & Holden, 2014; Msangi et al.,

	2024; Maku et al., 2023)

Sources: National Sample Census of Agriculture 2020

3.4. Robustness check of the assumptions of logistic models

Assumptions such as independence, no perfect collinearity, and linearity of the independent variables are crucial in logistic models (Harris, 2021). We performed a series of empirical checkups for data, variables, and models to ensure the data are normally distributed, no omitted variable, and the model is correctly specified. We performed the Shapiro–Wilk statistical test for normality of data; for multicollinearity, we conducted variance inflation factors (VIF); for omitted variable in a model, we tested for model specification errors to ensure robust results.

The Shapiro-Wilk test was used to test if the variables are normally distributed (Shapiro et al., 1965) such that H0: Variables are not normally distributed. If the chosen critical alpha level is greater than p-value, the null hypothesis is rejected, meaning that the variables under study are normally distributed. On the other hand, the chosen alpha value level is less than the p-value the above null hypothesis is accepted (Albert et al., 2020; King & Eckersley, 2019). We calculated using the Shapiro-Wilk formula expressed below as specified by Looney & Hagan (2007):

$$W = \frac{(\sum_{1=1}^{n} m_i y_{(i)})^2}{(\sum_{1=1}^{n} (y_i - \bar{y}_{(i)})^2} \qquad (iv)$$

Where, $\sum$ represents a summation sign, y_i is the ordered sample value, $\bar{y}$ is the mean of the sample, m_i represents the constants generated from the means of variances and covariances of ordered statistics, and n is the sample size from the assumed normal distribution.

The Shapiro-Wilk test (W) value lies between $(0 - 1)$. As the value approaches zero, it indicates the non-normality of the distribution, which facilitates rejection of the above null hypothesis, whereas the value approaches 1, confirms the normality (Looney & Hagan, 2007). The W value indicates that all variables are closer to 1, therefore, are normally distributed (King & Eckersley, 2019) as reported in Table 2.

Table 2. Shapiro-Wilk W test for normal data

Variable	Obs	W	V	z	Prob>z

DstHom_Farm	6,419	0.940	203.616	14.055	0.000
DstFarm_Mrkt	6,419	0.638	1224.083	18.797	0.000
Age	6,419	0.981	63.012	10.954	0.000
lnProfts	6,419	0.729	916.666	18.033	0.000

Obs. = Number of respondents; W=Wilk test; V = Variances; z = the ratio of the coefficient to the standard error of the predictor respectively.

Sources: National Sample Census of Agriculture 2020

We calculate the variance inflation factors (VIFs) for the predictors in a model to identify if there is multicollinearity. It happens when two or more independent variables are correlated and can be used to predict each other. Summaries in Table 3 confirm that no variables exceed rules of thumb of 10 for decision (Brien, 2007). Table 3 indicates that there is no degree of multicollinearity of the predictors with the other predictors in a regression model. Implying each variable carries unique information about the response variable, supporting our inclusion of all the independent variables in the regression model.

Table 3. Variance inflation factor (VIFs)

Predictors	VIF	1/VIF
DstHom Farm	1.127	.888
DstFarm Mrkt	1.085	.922
Genrl Eductn	1.073	.932
NoFormalEdctn	1.071	.934
Off Fmincome	1.066	.938
Usge InfoChanels	1.065	.939
lnProfts	1.062	.942
Mmber Coprtive	1.052	.95
AcsesExtSev	1.049	.953
Use Tractor	1.042	.96
LandOwnshp	1.04	.961
Gender	1.032	.969
AcesAgrCredt	1.03	.971
Mmber FrmOrgztn	1.026	.975
Prctce Irgatn	1.02	.98
AgPrdctProcssng	1.016	.984
Age	1.007	.993
Mean VIF	1.051	.

Sources: National Sample Census of Agriculture 2020

We finally subjected the model to specification error. We had two assumptions: first, the link function of the response (outcome) variable on the left-hand side that the ordered logistic regression is a correct function to use. Secondly, we assume that our model has all the relevant independent variables (not included variables not required), and the logit function is a linear combination of the predictors, which is sufficient. To meet these two assumptions is important for the predicted value from the model (**_hat**) to be statistically significant, and (**_hatsq**) should be statistically insignificant because it should not have much predictive power. Our model is correctly specified such that (**_hat**) is statistically significant whereas (**_hatsq**) is not, as shown in Table 4.

Table 4. Specification error

AIIntnsty	Coefficients	Std. Error.	z	P>z	[95% conf.	interval]
_hat	1.004***	0.030	33.64	0.000	0.945	1.062
_hatsq	-0.050	0.032	-1.59	0.112	-0.112	0.012
LR chi2(2)	1363.89					
Prob > chi2	0.0000					
Pseudo R2	0.1187					
Log likelihood	-5064.2939					
Number of obs	6,419					

**** p<.01, ** p<.05, * p<.1*

Sources: National Sample Census of Agriculture 2020

4. Results and discussion

4.1. Descriptive analysis

Problems and challenges that were mentioned by youths during the survey are reported in Figure 3. The most critical problem that was reported is unreliable rainfall associated with floods, which accounts for 61% of the respondents. Agriculture is rain-fed and seasonal. Unreliable rainfall affects the harvest and discourages youth from holding on to agriculture. Sometimes they cultivate in lowland areas where floods affect their crops. Some never harvest due to unreliable rain and floods. This problem can be mitigated through investment in reliable irrigation systems.

Agriculture can be attractive and profitable. Good farming infrastructures motivate youth involvement (Kaki et al., 2022).

About 13% of youth reported pests and diseases as critical problems. Climatic change impacts (declining rain and increasing temperature) have resulted in eruptions of pests/diseases that affect the practices such as cash and food crops. Youth have limited resources for insecticides to control plant diseases. Some don't harvest, subsequently discouraging them from venturing in the sector. The problem can be mitigated through the provision of agricultural extensions and subsidies for agricultural inputs such as insecticides, pesticides, and fertilizers. Investments in agricultural science and biology, improve plant health and harvests that generate profits (The Alliance for a Green Revolution in Africa (AGRA), 2019).

About 9% of youths reported that prolonged drought is one of the problems they face and affects their well-being in agriculture. Prolonged drought due to climate change affects farming and eventually harvest and food availability. Drought discourages youth engagement in agriculture as they fail to meet their aspirations in life. The risk associated with drought can be minimized by adopting an irrigation system. The stakeholders can establish irrigation schemes in all productive zones. Youths can be encouraged to form groups that can be supported.

Youths were asked to report the challenges affected their involvement in the sector. About 78% of youth said low crop market prices is a critical challenge. Volatile crop prices affect harvest values and profits as production costs are increasing per hectare. Unreliable crop market prices push youth from the sector (The Alliance for a Green Revolution in Africa (AGRA), 2019). The impacts of unreliable crop prices include loan defaulting for loans invested in crop farming. To mitigate this challenge, stakeholders should establish strong and active farmers unions and crop boards that facilitate linking youth with reliable crop market locally and internationally. Reliable markets assure youth profits and attract more youths. Profits attract and retain youth in the sector to accrue the gains embedded in it (Muthomi, 2017).

About 6% of youth reported that markets are too far. Youth engaging in agribusiness fail to reach markets because of road constraints. The roads in rural areas allow seasonal passing, youth fail to transport their crops from farms/plots/homes/storages to markets. The impacts include getting loss and decaying of perishable crops and fruits, which forces them to sell at a low price. Also, transit of crops is too high, as reported by 3% of youth. High transport costs add production costs and cut off the profits after selling crops. Losses discourage farmers venturing into agricultural activities. The government can improve infrastructures such as roads, rural electrifications, and storage facilities. Evenly distributed infrastructures reduce time wastage, decaying of perishable crops and fruits, storage and processing of crops, and costs of transiting commodities from the production site to the markets (Mukwedeya & Mudhara, 2024; The Alliance for a Green Revolution in Africa (AGRA), 2019). Stakeholders should be encouraged to invest in the transport industry to create a good atmosphere for farmers to accrue the agriculture potentials.

Production inefficiency reported by 2% of youth. Agricultural production in developing economies is hampered by numerous obstacles (URT, 2016b; Maiga, 2016). The bottlenecks lead to poor harvest and some fail to harvest. Production inefficiency discourages youth from taking ventures into agriculture and opts to keep on searching for other jobs in other sectors. To deal with this challenge, the agricultural stakeholders can work in collaboration with youth in improving agricultural technologies, subsidizing inputs, controlling pests/diseases control, and implementing policy measures that put youth at the core. Dealing with these contemporary problems and challenges is crucial for pulling and retaining youths in the sector and making them good farmers of today and tomorrow (USAID, 2017).

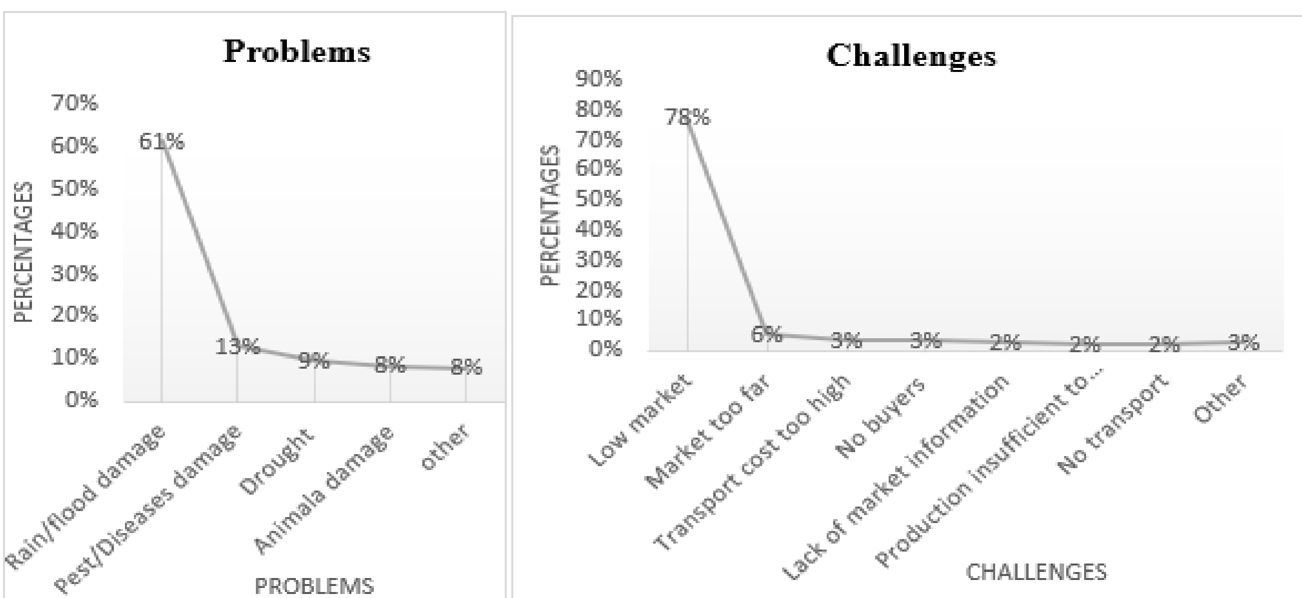

Figure 3. Factors hindering youth intensity of participation in agricultural activities
Source: National Sample Census of Agriculture 2020

4.2. Empirical results

We employed ordered logistic analysis in alignment with the hypotheses that economic, social, institutional, demographic, and environmental factors influence youths' rate of intensity participation in agricultural activities. The model, when compared to the null model without predictors, is statistically significant overall, with a likelihood ratio of 1361.373 and a p-value of 0.0000. The results are reported in Table 5.

Table 5. Results from ordered logistic regression

Variables	Odds Ratio	St. Error.	z	p>|z|
Youth intensity participation in Agriculture (AIIntnsty)				
Distance from home to Farm (DstHom_Farm)	1.001	.009	0.13	0.895
Distance to the market (DstFarm_Mrkt)	1.006**	.003	2.16	0.031
Age of a youth in years (Age)	.989	.007	-1.56	0.118
General education (Genrl_Eductn)	.661***	.043	-6.35	0.000
No form education (NoFormalEdctn)	1.151*	.088	1.83	0.067
Gender of a youth (Gender_ Male)	1.129	.09	1.53	0.126
Access to extension services (AcsesExtSev)	1.304***	.127	2.71	0.007
Usage of Information channels (Usge_InfoChanels)	1.478***	.12	4.79	0.000
Access to agricultural credit (AcesAgrCredt)	1.414**	.198	2.48	0.013
Access to irrigation (Prctce_Irgatn)	1.384***	.134	3.34	0.001
Use of advanced tools_Tractor (Use_Tractor)	1.444***	.08	6.61	0.000
Youth membership in Cooperatives (Mmber_Coprtive)	2.279***	.347	5.40	0.000
Youth in farmer Organization (Mmber_FrmOrgztn)	1.593**	.288	2.58	0.01
Profits from sales (lnProfts)	1.033***	.005	6.95	0.000

Youth with other income sources (Off_Fmincome)	.204***	.011	-28.47	0.000
Involvement in agroprocessing (AgPrdctProcssng)	1.31***	.106	3.35	0.001
Youth own a piece of land (LandOwnshp)	1.808***	.116	9.24	0.000
cut1	-.201	.235		
cut2	.135	.235		

Mean dependent var	0.997	SD dependent var	0.965
Pseudo r-squared	0.118	Number of obs.	6419
Chi-square	1361.373	Prob > chi2	0.000
Akaike crit. (AIC)	10169.105	Bayesian crit. (BIC)	10297.678

z is the ratio of the coefficient to the standard error of the respective independent variable.
Standard errors (SE) in parentheses: *** *p<.01,* ** *p<.05,* * *p<.1*
Sources: National Sample Census of Agriculture 2020

Factors such as land ownership are positively and statistically significant at 1%, influencing youth intensity participation in agricultural agribusiness. A unit increase in land ownership (moving from 0 to 1), the odds of youth high intensity of participation (full-time participants) compared to the combined middle (part-time participants) and low (not participants) categories are 1.808 greater, given that all other predictors in the model are kept constant. The same results were obtained by Martinson et al. (2019) and Msangi et al. (2024) that land ownership titling promotes youth engagement in agricultural activities. Land ownership is crucial for youth attraction in the sector (Bezu & Holden, 2014; Maku et al., 2023).

Use of farm machines (e.g. tractors) in agriculture is statistically significant at 1%, influencing youth involvement in agriculture. The results indicate that a unit increase in access and usage of machines (going from 0 to 1), the odds of high intensity of participation versus the combined low and middle intensity of participation in agriculture categories are 1.444 greater, holding other variables unchanged in the model. The use of machines increases youth participation in the sector. The results in this paper are in line with the results obtained by Mohammed et al. (2023) that mechanization in agriculture in developing countries is crucial as it attracts youth who are innovative and knowledgeable in the sector (Pliakoura & Beligiannis, 2023).

Access and usage of irrigation facilities is positive and statistically significant at 1%. A unit increase in irrigation facilities (going from 0 to 1), the odds of high intensity of participation compared to middle and low categories are 1.384 greater, keeping other factors constant. Variation in important elements of weather, such as temperature, rain, precipitation, and humidity, adversely affects farm performance, especially for resource-poor farmers. The establishment of reliable irrigation facilities will attract more farmers in the sector. Resilience in crop farming will be improved, which will eventually improve food availability and poverty reduction as youth will sell crops for income. Irrigation systems attract youth in the sector, as it has been revealed in other extant studies (Devkota, 2022).

Surprisingly, youth with formal education are less likely to fully participate in agriculture. It is negative and statistically significant at 1%. A unit increase in youth's formal education (shifting from 0 to 1), the odds of high intensity of participation versus the combined low and moderate catastrophic are .661 smaller, keeping other predictors unchanged. Youth with no formal education, the odds of high intensity of participation in agriculture compared to the combined moderate and low categories are 1.151 greater, assuming other variables are constant. Formal education increases the chance of searching for job opportunities in other sectors, unlike the uneducated youth, who remain with one option of engaging in agriculture. Educated youths' negative perceptions about agriculture have created an influx pool of unemployed and underemployed youths. It is important that education systems in developing sub-Saharan countries create awareness and reinforcement that promote youth careers in the sector. The result in this paper concur with several extant studies that education does not promote youth engagement in agriculture in many places (Albert et al., 2020; Devkota, 2022; Maku et al., 2023).

Youths' membership in farmers' cooperatives and organizations influences youth participation intensity and is both positive and statistically significant at 1% and 5%, respectively. A one-unit increase in cooperatives or organizations (going from 0 to 1), the odds of high intensity of participation versus combined moderate and low categories are 2.279 and 1.593 greater for cooperatives and organizations, respectively, holding other variables unchanged. Farmers' unions and associations play a great role in solving challenges facing the sector, such as marketing, inputs, and storage. They are crucial in attracting, promoting, and keeping youth in the sector. They are reported to influence the youth participation in agriculture as they formalize the sector for easy support from stakeholders (Daudu et al., 2023; Giwu et al., 2024; Maku et al., 2023).

For processing agricultural products, a unit increase in processing (moving from 0 to 1), the odds of high intensity of participation versus the combined moderate and low categories are 1.31 greater, keeping other variables constant. Processing widens the value chain in the agricultural sector. Creates more opportunities for youth venturing in the sector. Increase the value of the crops and market networking. Youth who don't like going farming still be involved in the sector in the processing sub-sector. The results in the article are in the light of other studies that processing is important in the modern economy to attract and keep youth in the sector, which leads to industrial expansion (Geza et al., 2023).

The variable profits in Tanzanian Shillings (TZS) reveal that with a one unit increase in a profit, the odds of high intensity of participation versus the low and moderate categories of intensity are 1.033 times greater, given that all other independent variables are held constant. Profit from agricultural activities such as agribusiness is subject to costs of operations. For instance, crop farming will have potential profits when input costs, interest rates, and other related costs are relatively low. The crop prices should be relatively high. The perceived profits accrued from agricultural activities play a role in youth decisions to participate in agriculture. Further, Devkota (2022) found that profit accrued from agricultural activities determines youth involvement in the sector.

For access to agricultural credit, a one unit increase in credit (shifting from 0 to 1), the odds of high intensity of participation in agriculture compared to combined low and middle categories are 1.414 greater, holding other predictors constant. Developing countries like Tanzania experience weak agricultural financing that leads to agricultural credit constraints (Mukasa et al., 2017; Girma, 2022). Credit is important to farming communities, enabling them to buy farm inputs, search market, and increase resilience in adverse climatic conditions. However, most youth are constrained due to lack of assets or resources to place as collateral (Mukasa et al., 2017). The same results found in others studies that credit is important for youth involvement in the sector (Daudu et al., 2023; Devkota, 2022; Giwu et al., 2024).

For access to extension services, a one unit increase in extension services (shifting from 0 to 1), the odds of high intensity of participation in agriculture versus the combined low and middle categories are 1.304 greater, keeping other factors constant. Meta-analysis has shown that extension service is crucial for transforming the agricultural sector. Trained agricultural officers can share useful information regarding agricultural performance through face-to-face or different platforms. Youth who have access to and use the expertise reveal high odd ratios of involvement in the sector (Daudu et al., 2023; Devkota, 2022; Franzel., 2019; Giwu et al., 2024).

The usage of information source channels such as radio, phone, internet, and TV to access agricultural information is positively and statistically significant at 1% influencing youth intensity of involvement in agriculture. So, a unit increase (going from 0 to 1), the odds of high intensity of participation versus the combined low and moderate categories are 1.478 greater, provided that other variables are unchanged. ICT platforms in agriculture attract youth in the sector. Youth are active users of ICT compared to elders (Sanga et al., 2013; Irungu et al., 2015). The use of information source channels simplifies information sharing in a short period of time to a large audience. Digital agriculture, which apparently could be a good form of agricultural practice that attracts youth. In many places studies have reported that mobile phone calls and SMS, online TV and videos, online radio, social media, blogs, GPS, and GIS, and TV reality shows have brought tremendous impact to farmers who share information about agriculture (Ogwu et al., 2023; Pliakoura & Beligiannis, 2023). Further, this result concur with the results of Daudu et al. (2023) and Maku et al. (2023), who found that access to markets using ICT is associated with participation in agricultural activities.

The distance to the nearest market indicates that with a one unit decrease in distance, the odds of high intensity of participation compared to moderate and low categories of intensity are 1.006 times greater, given that all other independent variables are held constant. Youth who are involved in the agricultural sector, especially in horticulture, need nearby markets to sell the perishable vegetables, spices, and fruits (Albert et al., 2020). Youth having access to markets increases agricultural products because of sales profits and good returns on investment in agriculture and value addition (Maku et al., 2023).

Lastly, having off-farm income is negatively and statistically significant at 1%, influencing youth intensity participation in agriculture. Off-farm income reveals that the odds of high intensity of participation compared to combined low and moderate categories are .204 greater, given that all other predictors are kept constant. This may imply that youth prefer to develop their careers in other sectors. Just like other parts of the globe, Tanzanian youth consider agricultural activities, especially farming, as less paying, low status, and associated with many hurdles (Losch, 2016; Chifupa & Tagwi, 2021). Youth who secure jobs in other sectors would not like being involved in agriculture (Cheteni et al., 2017; Maku et al., 2023).

4.3. Limitations of the study

The paper experiences some limitations. First, limitation may be emanated from data. We employed cross-section data, which fails to capture the time-variant influencing factors. Second, limitation may emanate from self-reported information, which might have jeopardized the estimation due to incorrect information.

5. Conclusion and policy implication

Youth involvement in agriculture is a global challenge, especially in the developing economies whose agricultural sector is the backbone of their economies. Youth Passover on agricultural activities harms the economy. This paper investigates the problems and challenges that hinder youth involvement in agriculture and the drivers influencing youth intensity participation.

The critical problems that hinder/discourage youth participation in agriculture include unreliable rain and floods, pests and diseases, and prolonged drought, whereas challenges include unreliable market prices, markets located far away, hight transport costs, lack of market information, and inefficient production.

The ordered logit model reported factors such as access to farm tools (tractors), agricultural credit, information source channels, extension services, land ownership, processing agricultural products, profits from sale in TZS, membership in farmers' cooperatives and organizations, distance to the nearest market, and land ownership and irrigation facilities positively and statistically significantly influencing full-time youth involvement in agriculture. However, factors such as off-farm income and general education are negative and statistically significant influencing youth intensity of participation.

The results from the ordered logit model survived a series of robustness checks of the underlying assumptions. We tested for normality, omitted variable, multicollinearity, and model specification error.

The findings in this paper have both policy and academic implications. First, on policy issues, the results suggest that stakeholders should provide youth support through drivers that affect them directly or indirectly. For instance, in terms of inspirations (communication through different information sources, radio, TV, social media, and the internet), emancipations (through extension services), engagement (through agricultural credit), enablement (through improved infrastructures such as roads, electrification, market networks, farm tools, and control of plant diseases), and coordination (effective utilization of scarce resources such as irrigation and schemes, conducting monitoring and evaluation of all initiatives).

Second, on academics, the findings indicate that general education is negatively related to youth involvement in agriculture. Implying that as youths get more education, they abandon agriculture. It is time for the education system (as a formal system) to teach agricultural-specific subjects to generate positive attitudes and perceptions of youth towards agriculture.

6. Declarations

Author contribution statement

Yohane Kitwima Magembe: Comprehended and designed the study; analysed and interpreted the

data, materials, analysis tools, and writing. Martin Bai: Proofreading, editing, and set up.

Funding statement

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Ethical declaration

This paper uses secondary data. At the time of data collection, clearance and permission from relevant authorities and informed consent from respondents were seriously adhered to.

Data availability statement

Data is available from NBS as NSCA 2019/20 with Ref.TZA-NBS-NSCA-2019-v01. The data can be downloaded from [https://www.nbs.go.tz/tnada]. For the case of this study, we downloaded on [20/05/2023].

Competing Interest

We declare no known competing interests.

Additional information

No extra information available for this paper.

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References

Adamon N. Mukasa, Anthony M. Simpasa, and A. O. S. (2017). *Credit constraints and farm productivity: Micro-level evidence from smallholder farmers in Ethiopia. Working Paper Series No. 247. African Development Bank Group* (Issue 247, pp. 1–40).

Adeyanju, D., Mburu, J., & Mignouna, D. (2021). *Youth Agricultural Entrepreneurship :*

Assessing the Impact of Agricultural Training Programmes on Performance. 1–11.

Akrong, R., & Hundie, B. (2022). Heliyon Economic analysis of youth participation in agripreneurship in Benin. *Heliyon*, *8*(December 2021), e08738. https://doi.org/10.1016/j.heliyon.2022.e08738

Alan Agresti. (2010). Analysis ofOrdinal Categorical Data, Second Edition. *John Wiley & Sons, Inc.*, 1–8.

Albert, A., Hepelwa, A., Yami, M., & Manyong, V. (2020). *Assessment of Factors Influencing Youth Involvement in Horticulture Agribusiness in Tanzania : A Case Study of Njombe Region*.

Ali, D. A., Collin, M., Deininger, K., Dercon, S., Sandefur, J., & Zeitlin, A. (2014). *The Price of Empowerment : Experimental Evidence on Land Titling in Tanzania Working Paper 369 May 2014*. *May 2014*.

Arenius, P., & Minniti, M. (2005). Perceptual variables and nascent entrepreneurship. *Small Business Economics*, *24*(3), 233–247. https://doi.org/10.1007/s11187-005-1984-x

Asare-Nuamah, P., Botchway, E., Dick-Sagoe, C., Asamoah, J. O., Kabanda, U., & Anane-Aboagye, M. (2024). Agriculture knowledge and youth participation in agriculture and agribusiness in an African context. *Development in Practice*, 1–21. https://doi.org/10.1080/09614524.2024.2402480

August, M. M. (2020). *Youths' aspirations and perceptions towards agricultural participation: a case of two Free State regions (Doctoral dissertation, University of the Free State).*

Bezu, S., & Holden, S. (2014). Are rural youth in ethiopia abandoning agriculture? *World Development*, *64*, 259–272. https://doi.org/10.1016/j.worlddev.2014.06.013

Blattman, C., & Jeannie Annan. (2011). *Evidence from Randomized Evaluations of Peacebuilding in Reintegrating and Employing High Risk Youth in Liberia : Lessons from a randomized evaluation of a Landmine Action agricultural training program for ex-combatants Table of Contents*.

Boye, M., Ghafoor, A., Wudil, A. H., Usman, M., Prus, P., Feh, A., & Sass, R. (2024). *Youth Engagement in Agribusiness : Perception , Constraints , and Skill Training Interventions in Africa : A Systematic Review*.

Brien, R. M. O. (2007). *A Caution Regarding Rules of Thumb for Variance Inflation Factors*. 673–690. https://doi.org/10.1007/s11135-006-9018-6

Cheteni, P., Municipality, D., & Africa, S. (2017). *Youth Participation in Agriculture in the Nkonkobe District Municipality , South Africa Youth Participation in Agriculture in the Nkonkobe*. *9274*. https://doi.org/10.1080/09709274.2016.11907025

Chipfupa, U. & Tagwi, A. (2021). Youth ' s participation in agriculture : A fallacy or achievable possibility ? Evidence from rural South Africa. *South African Journal of Economic and Management Sciences ISSN: (Online) 2222-3436, (Print) 1015-8812*, 1–12.

Daudu, A. K., Abdoulaye, T., Bamba, Z., Shuaib, S. B., & Awotide, B. A. (2023). Does youth participation in the farming program impact farm productivity and household welfare ? Evidence from Nigeria. *Heliyon*, *9*(4), e15313. https://doi.org/10.1016/j.heliyon.2023.e15313

Daum, T., Ygu, P., Adegbola, C., Daudu, C., Issa, F., Kamau, G., Oumar, A., Mose, L., Ndirpaya, Y., Fatunbi, O., Zossou, R., Kirui, O., & Birner, R. (2022). *Mechanization , digitalization , and rural youth - Stakeholder perceptions on three mega-topics for agricultural transformation in four African countries*. *32*.

https://doi.org/10.1016/j.gfs.2022.100616
Deininger, K., & Feder, G. (2009). *Land Registration , Governance , and Development : Evidence and Implications for Policy*. 233–266.
Devkota, N. (2022). *Awareness on agricultural entrepreneurship among youth farmers : an empirical study from Western Nepal*. *13*(5), 812–830. https://doi.org/10.1108/JADEE-06-2021-0150
Douglas Nyathi, Joram Ndlovu, N. N. & K. P. (2022). The Dynamics of Promoting Youth Participation in Smallholder Agriculture for Sustainable Food Security in Lupane District, Zimbabwe. *Sustainable Agriculture and Food Security*. https://doi.org/10.1007/978-3-030-98617-9
Esters & Bowen. (2005). *Factors influencing career choices of urban agricultural education students*. *46*(2), 24–35. https://doi.org/10.5032/jae.2005.02024
FAO. (2014). *FAO Regional Conference for Africa: African Youth in Agribusiness and Rural Development* (Issue January, p. 11). Tunis, Tunisia, 24-28 March 2014.
Franzel, S., Kinyua, H., Rucibigango, M., Davis, K., and Makh, S. (2019). *Youth in Extension and Advisory Services: Rwanda. Developing Local Extension Capacity Project. USAID, Washington D.C. August*.
Geza, W., Ngidi, M., Ojo, T., Adetoro, A. A., Slotow, R., & Mabhaudhi, T. (2021). Youth participation in agriculture: A scoping review. *Sustainability (Switzerland)*, *13*(16), 1–15. https://doi.org/10.3390/su13169120
Geza, W., Simon, M., Ngidi, C., Mudhara, M., & Mabhaudhi, T. (2023). ' Is there value for us in agriculture ?' A case study of youth participation in agricultural value chains in KwaZulu-Natal , South Africa ' Is there value for us in agriculture ?' A case study of youth participation in agricultural value chains. *Cogent Food & Agriculture*, *9*(2). https://doi.org/10.1080/23311932.2023.2280365
Girma, Y. (2022). Credit access and agricultural technology adoption nexus in Ethiopia : A systematic review and meta-analysis. *Journal of Agriculture and Food Research*, *10*(March), 100362. https://doi.org/10.1016/j.jafr.2022.100362
Giwu, O., Mdoda, L., & Ntlanga, S. S. (2024). Assessing the socio-economic impact of youth engagement in agricultural enterprise for employment creation and poverty alleviation. *Cogent Social Sciences*, *10*(1). https://doi.org/10.1080/23311886.2024.2368097
Greene, W. H. (2003). *Econometric analysis, Fifth Edition*.
Greene, W. H. (2012). Econometric Analysis. In *Litigation Services Handbook: The Role of the Financial Expert: Sixth Edition* (7th ed.). https://doi.org/10.1002/9781119363194.ch9
Guo, G., Wen, Q., & Zhu, J. (2015). *The Impact of Aging Agricultural Labor Population on Farmland Output : From the Perspective of Farmer Preferences*. *2015*, 7. https://doi.org/http://dx.doi.org/10.1155/2015/730618
Haji Athumani Msangi, Betty Waized, Daniel Wilson Ndyetabula, V. M. M. (2024). Heliyon Promoting youth engagement in agriculture through land titling programs : Evidence from Tanzania. *Heliyon*, *10*(7), e29074. https://doi.org/10.1016/j.heliyon.2024.e29074
Harris, J. K. (2021). *Primer on binary logistic regression*. 1–7. https://doi.org/10.1136/fmch-2021-001290
Heifer International. (2021). *The future of Africa's agri- culture - an assessment of the role of youth and technology. https://media.heifer.org/About_Us/ Africa-Agriculture-Tech-2021.pdf.*

Henning, J. I. F., Matthews, N., August, M., & Madende, P. (2022). *Youths ' Perceptions and Aspiration towards Participating in the Agricultural Sector : A South African Case Study*.

Irungu, K. R. G., Mbugua, D., & Muia, J. (2015). *Information and Communication Technologies (ICTs) Attract Youth into Profitable Agriculture in Kenya Information and Communication Technologies (ICTs) Attract*. *8325*. https://doi.org/10.1080/00128325.2015.1040645

Janzen, T. (2014). *Environmental. Legal news rooms. https://www.lexisnexis.com/legalnewsroom/environ mental/b/environmentalregulation/posts/the-chal lenges-facing-liberian-agriculture*. 2014.

Jayne, T.S., Sanchez, P. A. (2021). *Agricultural productivity must improve in sub-Saharan Africa. Science 372 (6546), 1045–1047*. *372*(6546), 1045–1047.

Kafle, K., Paliwal, N., & Benfica, R. (2019). Who Works in Agriculture? Exploring the Dynamics of Youth Involvement in the Agri-Food Systems of Tanzania and Malawi. In *SSRN Electronic Journal* (Issue June). https://doi.org/10.2139/ssrn.3366984

Kaki, R. S., Mignouna, D. B., Aoudji, A. K. N., Adéoti, R., Kaki, R. S., Mignouna, D. B., Aoudji, A. K. N., Adéoti, R., & Kaki, R. S. (2022). *Entrepreneurial Intention among Undergraduate Agricultural Students in the Republic of Benin Entrepreneurial Intention among Undergraduate Agricultural Students in the Republic of Benin*. https://doi.org/10.1080/15228916.2022.2031584

Kalya Dennis Maritim. (2020). *Assessment of Factors Influencing Youth Participation in Agri-Business in Kericho County, Kenya (Doctoral dissertation, KeMU).*

Kaplan, S., & Prato, C. G. (2012). Risk factors associated with bus accident severity in the United States : A generalized ordered logit model. *Journal of Safety Research*, *43*(3), 171–180. https://doi.org/10.1016/j.jsr.2012.05.003

Karen Brooks, Sergiy Zorya, Amy Gautam, & Goyal, A. (2013). *Agriculture as a sector of opportunity for young people in Africa (pp. 64–73). World Bank Policy Research Working Paper.*

King, A. P., & Eckersley, R. J. (2019). *Inferential Statistics IV: Choosing a Hypothesis Test. Statistics for Biomedical Engineers and Scientists, 147–171. doi:10.1016/b978-0-08-102939-8.00016-5*. 147–171. https://doi.org/10.1016/B978-0-08-102939-8.00016-5

Krumboltz, J. D., Mitchell, A. M., & Jones, G. B. (1976). *The Counseling Psychologist*. https://doi.org/10.1177/001100007600600117

Liñán, F., Santos, F. J., & Fernández, J. (2011). The influence of perceptions on potential entrepreneurs. *International Entrepreneurship and Management Journal*, *7*(3), 373–390. https://doi.org/10.1007/s11365-011-0199-7

Looney, S. W., & Hagan, J. L. (2007). Analyzing Biomarker Data. In *Essential Statistical Methods for Medical Statistics: A derivative of Handbook of Statistics: Epidemiology and Medical Statistics, Vol. 27* (Vol. 27, Issue 07). Elsevier B.V. https://doi.org/10.1016/B978-0-444-53737-9.50005-0

Losch, B. (2016). Structural transformation to boost youth labour demand in Sub-Saharan Africa : the role of agriculture, rural areas and territorial development. *Employment Working Paper ; No. 204 1999-2939*.

Lucy Karega Njeru. (2017). Youth in Agriculture ; Perceptions and Challenges for Enhanced Participation in Kajiado North Sub-County, Kenya. *Greener Journal of Agricultural Sciences*, *7*(8), 203–209. https://doi.org/10.15580/GJAS.2017.8.100117141

Magagula, B., & Tsvakirai, C. Z. (2019). Development in Practice Youth perceptions of agriculture : influence of cognitive processes on participation in agripreneurship. *Development in Practice*, *0*(0), 1–10. https://doi.org/10.1080/09614524.2019.1670138

Magagula, B., & Tsvakirai, C. Z. (2020). Development in Practice Youth perceptions of agriculture : influence of cognitive processes on participation in agripreneurship. *Development in Practice*, *30*(2), 234–243. https://doi.org/10.1080/09614524.2019.1670138

Maiga, E. W. H. (2016). Determinants of changes in youth and women agricultural labor participation in selected African countries. *Agricultural & Applied Economics Association Annual Meeting*, 1–18.

Maku, M., Kitambo, E., Mugonola, B., Maku, M., & Kitambo, E. (2023). *Drivers of youth participation in maize value addition in Gulu district , Uganda*. https://doi.org/10.1080/20421338.2021.2015171

Martinson, A. T., Yuansheng, J., & Monica, O. A. (2019). Determinants of agriculture participation among tertiary institution youths in Ghana. *Journal of Agricultural Extension and Rural Development*, *11*(3), 56–66. https://doi.org/10.5897/JAERD2018.1011

Mcmullin, J. R. (2022). *Hustling , cycling , peacebuilding : Narrating postwar reintegration through livelihood in Liberia*. 67–90. https://doi.org/10.1017/S0260210521000255

Mdege, N., Mayanja, S., & Mudege, N. N. (2022). Youth engagement in sweetpotato production and agribusiness : the case of Northern Uganda. *Third World Quarterly*, *43*(10), 2430–2449. https://doi.org/10.1080/01436597.2022.2094236

Mengistu, M. (2017). Graduate Employability as a Function of Career Decision in the Amhara State TVET System. *Ethiopian Journal of Education and Sciences*, *13*(1), 1–21.

Miriti, G. M. (2020). An Exploration of Entrepreneurial Intentions among University Students in Kenya. *International Journal of Research and Innovation in Social Science (IJRISS)*, *IV*(Xii), 521–529.

Mmbengwa, V. M., Qin, X., & Nkobi, V. (2021). Determinants of youth entrepreneurial success in agribusiness sector: the case of Vhembe district municipality of South Africa. *Cogent Social Sciences*, *7*(1). https://doi.org/10.1080/23311886.2021.1982235

Mohammed, K., Batung, E., Ansumah, S., Mosonsieyiri, M., & Luginaah, I. (2023). Land Use Policy Determinants of mechanized technology adoption in smallholder agriculture : Implications for agricultural policy. *Land Use Policy*, *129*(March), 106666. https://doi.org/10.1016/j.landusepol.2023.106666

Mukembo, S. C., Edwards, M. C., Ramsey, J. W., & Henneberry, S. R. (2014). *Attracting Youth to Agriculture : The Career Interests of Young Farmers Club Members in Uganda*. *55*(5), 155–172. https://doi.org/10.5032/jae.2014.05155

Mukwedeya, B., & Mudhara, M. (2024). *Factors affecting rural youth participation in the smallholder farming sector*. *13*(4).

Mulema, J., Mugambi, I., Kansiime, M., Chan, H. T., Pham, T. X., Oduor, G., Mulema, J., Mugambi, I., Kansiime, M., & Chan, H. T. (2021). *Development in Practice Barriers and opportunities for the youth engagement in agribusiness : empirical evidence from Zambia and Vietnam*. https://doi.org/10.1080/09614524.2021.1911949

Muthomi, E. (2017). Challenges and opportunities for youth engaged in agribusiness in Kenya. *Journal of Culture, Society and Development*, *17*(1), 4–19.

Niels Bosma, Stephen Hill, Aileen Ionescu-Somers, Donna Kelley, Maribel Guerrero, T. S. (2021). *“Global entrepreneurship monitor 2020/2021 report,” 2021, https://www.gemconsortium.org/report/gem-20202021- global-report* (pp. 1–214).

Ninson, J., & Brobbey, M. K. (2023). "Review on engaging the youth in agribusiness”, Cogent Social Sciences, 9:1, 2193480, DOI: 10.1080/23311886.2023.2193480. *Cogent Social Sciences*, *9*(1). https://doi.org/10.1080/23311886.2023.2193480

Ogwu, C. A., Ogwo, C. A., Obichili, M. I., Chinweobo-onuoha, B. N., Charles, C. E., Gever, E. R., & Gever, V. C. (2023). *Using TV Reality Shows as a Platform to Influence Behavioural Youths*. https://doi.org/10.1177/00219096231188942

Omulo, G., Daum, T., Köller, K., & Birner, R. (2024). Unpacking the behavioral intentions of ‘emergent farmers’ towards mechanized conservation agriculture in Zambia. *Land Use Policy*, *136*(December 2020). https://doi.org/10.1016/j.landusepol.2023.106979

Osabohien, R., Wiredu, A. N., Matin, P., Nguezet, D., Mignouna, D. B., Abdoulaye, T., Manyong, V., Bamba, Z., & Awotide, B. A. (2021). *Youth Participation in Agriculture and Poverty Reduction in Nigeria*. 1–19.

Ouko, K. O., Ogola, J. R. O., Adino, C., Wairimu, R., Okoth, K., Ogola, J. R. O., & Adino, C. (2022). Youth involvement in agripreneurship as Nexus for poverty reduction and rural employment in Kenya SOCIOLOGY | REVIEW ARTICLE Youth involvement in agripreneurship as Nexus for poverty reduction and rural employment in. *Cogent Social Sciences*, *8*(1). https://doi.org/10.1080/23311886.2022.2078527

Parker, S. C. (1934). *Entrepreneurship and economic theory*. https://doi.org/10.1093/oxrep/gry013

Pindado, E., & Sánchez, M. (2017). Researching the entrepreneurial behaviour of new and existing ventures in European agriculture. *Small Business Economics*, *49*(2), 421–444. https://doi.org/10.1007/s11187-017-9837-y

Pliakoura, A., & Beligiannis, G. (2023). *Exploring the determinants of young agripreneurs ’ success toward sustainable agriculture : a regression approach*. https://doi.org/10.1108/MSAR-05-2023-0027

Sanga, C., Kalungwizi, V. J. & C. P. M. (2013). Building an agricultural extension services system supported by ICTs in Tanzania : Progress made , Challenges remain C . Sanga , V . J . Kalungwizi , and C . P . Msuya. *International Journal of Education and Development Using Information and Communication Technology (IJEDICT)*, *9*(1), 80–99.

Schierhorn, M. E. & F. (2016). Global Demand for Food Is Rising . Can We Meet It ? *Harvard Business Review*.

Schumpeter, J. A. (1934). *The Theory of Economic Development, Cambridge MA, Harvard University Press. 3*(2), 137–148.

Shapiro, S. S., Wilk, M. B., & Laboratories, B. T. (1965). *An analysis of variance test for normality (complete samples)!*

Shayo, A. H. (2020). *The Role Of Education System In Preparing Youth For Agricultural Career Decisions And Aspirations: Exploring Ways To Attract More Youth To Engage In Agriculture And Agricultural Entrepreneurship In Tanzania. Dissertation submitted to the faculty of the Vi*.

Sumberg, J., Yeboah, T., Flynn, J., & Anyidoho, N. A. (2017). *Young people ’ s perspectives on farming in Ghana : a Q study*. 151–161. https://doi.org/10.1007/s12571-016-0646-y

The Alliance for a Green Revolution in Africa(AGRA). (2015). *Africa Agriculture Status Report: Youth in Agriculture in Sub-Saharan Africa. Nairobi, Kenya. Issue No. 3* (pp. 1–232).

The Allience for a Green Revolution in Africa (AGRA). (2019). *Youth Strategy : Empowering* *youth for agricultural transformation. West End Towers, 4th Floor Kanjata Road, Muthangari Drive, Waiyaki Way P.O. Box 66773, Westlands 00800 Nairobi, Kenya* (pp. 1–12).

The Master Card Foundation. (2017). *Young Africa Works Summit 2017 Report in Kigali Rwanda.* (pp. 1–117).

Thephavanh, M., Philp, J. N. M., Nuberg, I., & Denton, M. D. (2023). Exploring demographic influences on perceptions of agricultural entrepreneurship as a career choice among Lao youth. *Development in Practice*, *33*(7), 811–824. https://doi.org/10.1080/09614524.2023.2183831

Triana ´Angel Natalia, B. S. (2023). *Youth in livestock and the power of education : The case of " Heirs of*. *97*(December 2022), 405–415. https://doi.org/10.1016/j.jrurstud.2022.12.032

Udemezue, J. (2019). Agriculture for All ; Constraints to Youth Participation in Africa. *Curr Inves Agri Curr Re*, *7*(2), 904–908. https://doi.org/10.32474/CIACR.2019.07.000256

Unity, Chifupa & Aluwani, T. (2021). Youth ' s participation in agriculture : A fallacy or achievable possibility ? Evidence from rural South Africa. *South African Journal of Economic and Management Sciences*, *24*(1), a4004. https://doi.org/https://doi.org/10.4102/sajems.v24i1.4004

URT. (2003). *Small and Medium Enterprise (SMEs) Development Policy 2002* (pp. 1–42).

URT. (2007). *National Youth Development Policy* (pp. 1–33). Ministry of Labour, Employment and Youth Development.

URT. (2008). *National Employment Policy 2008* (pp. 1–58).

URT. (2013). *National Agriculture Policy - 2013* (Issue October). MINISTRY OF AGRICULTURE FOOD SECURITY AND COOPERATIVES DAR.

URT. (2016). National Strategy for Youth Involvement in Agriculture. In *Ministry of Agriculture Livestock and Fisheries* (pp. 2016–2021).

URT. (2017). *Agricultural Sector Development Programme Phase II (ASDP II) November, 2017*.

URT. (2022). *Building A Better Tomorrow: Youth Initiative For Agribusiness (BBT-YIA) 2022-2030* (pp. 1–62).

USAID. (2017). *Global Highlights: USAID Youth Programs*.

van Dijk, W. F. A., Lokhorst, A. M., Berendse, F., & de Snoo, G. R. (2016). Factors underlying farmers' intentions to perform unsubsidised agri-environmental measures. *Land Use Policy*, *59*, 207–216. https://doi.org/10.1016/j.landusepol.2016.09.003

Veettil, P. C., Raghu, P., & Mohapatra, B. (2021). *Development in Practice Gender differences in rice value chain participation and career preferences of rural youth in India*. https://doi.org/10.1080/09614524.2020.1804840

Verick, S. (2009). *Who Is Hit Hardest during a Financial Crisis ? The Vulnerability of Young Men and Women to Who Is Hit Hardest during a Financial Crisis ? The Vulnerability of Young Men and Women to Unemployment in an Economic Downturn*. *4359*.

Williams, J., Daily, G., Noble, A., Matthews, N., Gordon, L., Wetterstrand, H., Declerck, F., Shah, M., Steduto, P., Fraiture, C. De, Hatibu, N., Unver, O., Bird, J., & Sibanda, L. (2016). *Sustainable intensification of agriculture for human prosperity and global sustainability*. https://doi.org/10.1007/s13280-016-0793-6

Wole-Alo I. Felicia, Falase O. Emmanuel, A. T. O. (2016). Assessing the future of agriculture in the hands of rural youth in oriade local government area of osun state, Nigeria. *International Journal of Agricultural Extension*, *4*(2), 105–110.

World Bank (WB). (2011). World development report 2011: Conflict, Security, and Development. *The World Bank, 1818 H Street NW, Washington, DC 20433, USA; Fax: 202-522-2422; e-Mail: Pubrights@worldbank.Org.*

Wuni, I. Y., Boafo, H., & Dinye, R. D. (2017). *Examining the Non-Participation of Some Youth in Agriculture in the Midst of Acute Unemployment in Ghana*. *November*.

Yami, M., Feleke, S., Abdoulaye, T., Alene, A. D., Bamba, Z., & Manyong, V. (2018). African Rural Youth Engagement in Agribusiness: Achievements, Limitations, and Lessons; Mercy Corps. Liberian Youth Reflect on Agriculture Livelihoods. *Sustainability*. https://doi.org/10.3390/su11010185

Zidana, R., Kaliati, F., & Shani, C. (2020). Assessment of youth engagement in agriculture and agribusiness in Malawi : Perceptions and hindrances. *Journal of Entrepreneurship and Management*, *9*(1), 19.

Youth Higher Intensity, Higher Gains? Empirical Evidence from Crop Farming in Tanzania

Abstract

Agriculture and youth are two of the mega topics in the 21st century. Agriculture is essential for livelihoods and economic growth. Youth can drive the sector today and in the future if attracted to being involved in it. Their involvement can create jobs and improve farm performance for economic growth. The extant understanding indicates that initiatives have not produced the desirable youth participation in the sector. The impacts of low youth buy-in in agriculture include youth unemployment, food insecurity, and poverty. Further, academic investigations have focused on contextual factors, challenges, attitudes and perceptions, and the impact of training programs to win higher youth buy-in in agriculture. However, studies about the impact of youth intensity of participation in agriculture on farm performance are scanty. Using a nationally representative sample of data from the National Sample Census of Agriculture (NSCA) of 2020, we examined the impact of youth intensity of participation in agriculture on crop yields, net returns, and return on investment (ROI). We adopt a doubly robust IPWRA estimator backed by PSM and ESR models. The average treatment on the treated (ATT) for crop yields, net returns, and return on investment (ROI) is higher for higher-intensity participants. The results suggest that effective interventions promoting youth investment in agriculture are crucial for youth to accrue the potential of agriculture.

Key Words: Tanzania, impact, intensity, agriculture, IPWRA, ESR, youth involvement.

1. Introduction

There is no universal agreement on who is youth. Youth is defined in context and for the purposes of the definition (Srinivasan, 2024). In Tanzania and in this study, youth is a person aged between 15 and 35 years old (Msangi et al., 2024; URT, 2022). Tanzania has the youngest population worldwide, with an 18-year median age, accounting for 31% of the total population, behind the median age for Africa (20 years), Asia (30 years), and Europe (40 years) (World Population Review, 2022). They enter the labour market (URT, 2022).

Promoting youth engagement in the agricultural sector and developing them into good future crop producers remains a global challenge. As a result, the youth unemployment crisis is exacerbating, particularly in Sub-Saharan Africa (SSA), Asia, and the Pacific due to their economies overdependence on agriculture (Awotide et al., 2016). Many places in developing nations experience threats to social cohesion, political stability, food security, and poverty reduction partly because youth neglect agriculture (World Bank (WB), 2011). They increase the pool of jobless and underemployed people, especially in the Global South.

To date, agriculture remains a crucial sector to foster economic growth, food security, and poverty reduction in developing countries (Diao et al., 2010; Sakketa & Gerber, 2017; Shayo, 2020). In Tanzania, agriculture supports more than 80% of livelihoods, 75% of the total labour force, 70% of rural incomes come from food and cash crops, 65% of industrial raw materials, 30% of export earnings (URT, 2016b; URT, 2017), and 26.1% of GDP (URT, 2021). Farming contributes more than 52% of new jobs in the labour market (URT, 2022).

Currently, agriculture holds the potential to employ a large population, as less than 25% of 44 million hectares of arable land has been utilized, of which 29.4% is potential for irrigation (Tumbo et al., 2017). Underutilization of fertile land is partly associated with youth neglect of agriculture and is a critical problem (URT, 2022).

On average, one million Tanzanian youth enter the labour market per year, and only 25% get employed (URT, 2021). They make up 56% of Tanzania's active youth labour force, where most of them are jobless, underutilized, or working in precarious situations more than adults (African Development Bank (AfDB), 2016). Promoting youth involvement in the sector is ideal as an immediate solution to youth unemployment.

The soaring youth population can be a national's competitive benefit if it is utilized in the economy (URT, 2016); they may boost GDP 10 times (African Development Bank (AfDB), 2016). They are energetic, quick learners, more productive, avid users of emerging technologies, and eager to learn and try new things more than elders (URT, 2022).

However, Tanzania experiences youth dynamics participation in agriculture, and even those who participate cannot stay longer (Lindsjö et al., 2020). They keep on searching for new job opportunities in other sectors. They only engage in agricultural activities if there are market failures in other sectors (Kafle et al., 2019). Youth engaging in agriculture are fewer and have been a challenge for many decades (URT, 2008), and the number of youth engaging is decreasing (Shayo, 2020). For instance, there were about 16 million youths, where only 48.8% are involved in farming; the population unemployment rate is 12.7%, while youth unemployment is higher than 50% (Shayo, 2020). Youths' unemployment is accelerated by mismatches between skills and market demand (Morsy & Mukasa, 2019), few job creations in other sectors (Shayo, 2020), and youth choosing agriculture as the last option (Rutta, 2012; Kafle et al., 2019). Subsequently, about 11.8% of youth are underemployed and the number of unemployed youth is rising (Lindsjö et al., 2020).

Furthermore, the agricultural sector does not attract due to hardships such as primitive tools (hand hoes), high farm-input costs; climate change and variability; limited capital and access to financial services; inadequate credit support; multiple taxes and levies; unpredictable crop prices (URT, 2016b; Maiga, 2016); limited agricultural entrepreneurial skills; poor access to land, markets, and information; poor business environment; lack of modern agricultural tools and digital technologies; limited access to farm inputs and extension services; weak youth groups, and poor coordination and motivation (Shayo, 2020; URT, 2022)

The persistence of the bottlenecks makes agriculture less attractive and not a preferable career for youth, despite the immediate gains in it. Subsequently, low youth engagement in agricultural activities (IFAD, 2019). The impacts on the economy, which are partly associated with youth negligence towards agriculture in Tanzania, include national food insecurity, persistence of unemployment and poverty, gradual commercialization of agriculture, low crop exports, and scant industrial development (Chakrabarti, 2018; Lindsjö et al., 2020). The planned growth of the sector of 10% by 2030 has not been reached, and there is a high import of processed foods (URT, 2022) and threats to peace and sustainable development (African Development Bank (AfDB), 2016).

As a response to youth negligence about agriculture, the government has put in place different initiatives, including state-led, development partners (DPs), non-governmental organizations (NGOs), companies, and individuals (URT, 2022).

Youths have the physical fitness that is required to manage agricultural practices (Maiga, 2016). Some studies show the relationship between youth participation and agricultural performance. In developing countries where contract farming is famous, youths who are involved in the training and programs augmented their paddy and beans productivity, and revenue (Kaki et al., 2022).

Research shows that skill training programs significantly boost agricultural productivity and income. Some studies show that engaging young people in crop farming improved rice output and income. Stakeholders should prioritize skill training initiatives to boost farm performance and promote younger generation engagement, especially in rural areas reliant on agriculture (Dooley & Schreckhise, 2016; Fasakin et al., 2022; Gordillo & Prescott, 2023).

Over recent years, the emphasis on youth participation in agriculture has been the option for many policies, especially in the developing countries that experience rising populations and labour skills mismatch in the labour markets. Many sectors of the economies fail to absorb all job seekers. The agricultural sector can absorb unemployed youths when other sectors are unable to employ them (Kafle et al., 2019). The sector can provide immediate gains to skilled and unskilled labourers.

Also, a level of intense participation in crop farming is associated with advantages such as changing traditional farming methods and adopting efficient technologies, active engagement in the farm programs and extension services, which reduces uncertainty in agricultural practices. Further, youth participating in agriculture as full-time jobs can observe the usefulness of farm inputs such as seeds, pesticides, insecticides, fertilizers, and new technologies adopted.

Provided these evident advantages that youth can accrue by through intensity engagement in agriculture, understanding the nexus between youths' levels of participation and farm performance is likely to offer useful evidence to effectively increase the promotion of youth participation. However, the evidence on how youths' intensity of participation in agriculture impacts farming performance remains scanty.

The contribution to the extant literature of this paper is threefold: first, we estimate the impact of youths' intensity of engagement in crop farming on the crop yields, net returns, and returns on investment (ROI). The existing studies focus mainly on crop productivity and revenue (Fasakin et al., 2022). Also, studies in Tanzania focus on farmers' productive efficiency on gross yields (Kidane et al., 2013; Miho, 2018; Ng'Atigwa et al., 2022; Selejio et al., 2018). In this study we add net returns and ROI, and the focus is on youth. They are crucial variables as they consider not only the gross harvests of crop production but also the associated crop production costs. They reflect the efficiency of what youths have invested on farm activities.

Secondly, the paper contributes to literature in terms of empirical method. We adopt an Inverse Probability Weighted Regression Adjustment (IPWRA) estimator to address the selection bias, which is linked with self-selected youth intensity of participation in agriculture. The impact studies heavily rely on the Propensity Score Matching (PSM) approach to address the selection bias. The only weakness of the PSM approach is the violation of the underlying assumption of correct specification of the select/choice/treatment equation. Then the PSM results would be considered consistent and unbiased, without bearing in mind the outcome equation. However, incorrect specification of the outcome equation would also lead to inconsistencies and biased estimates (Ma et al., 2018). To add to the IPWRA estimator, we have compared the results from PSM and Endogenous Switching Regression (ESR) models. We wanted to tackle the selection bias when estimating the impact of youth intensity of involvement in agriculture on crop yields, net returns, and ROI.

Third, the study contributes to policymakers when formulating policy measures to win youth's higher buy-in in agriculture. These findings in this paper outline that higher intensity equals higher gains. It is useful to have evidence-based and flexible policy measures when dealing with a socially dynamic group of youths.

The structure of this paper is as follows: Section 2 establishes the literature review and the estimation approach. Section 3 depicts the data and descriptive analysis. Section 4 presents the empirical results and discussions. Section 5 provides the conclusion and policy implications.

2. Literature review and the estimation approach

2.1. Theoretical framework

The decision to whether to partially or intensively involve in crop farming is subject to the anticipated gains from crop farming. The utility theory explains that human behaviour in making decisions is determined by the anticipated benefits regarding the decision. So, youth in Tanzania is thought that, can making decisions to engage in agricultural activities either full or part-time on when the gain in equation (i) is greater than 0

Thus,

$$U_{1i}^{*} = Y_{1i} - Y_{0i} > 0 \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (i)$$

The benefits or costs of the intensity of participation in crop farming may be accrued by whoever is engaging in, either full-time or part-time. Full participation in the crop farming program improves the understanding of the science and art of crop farming. Full participation in the crop farming project improves crop production, marketing decisions, farming methods, and early noticing of any change in crop progress. Youth's intensity of participation in crop farming may directly impacts crop yields per hectare as it improves farmers' farming experience (Fasakin et al., 2022). Eventually, be able to deal with problems and challenges in real field situations. The process from crop farming to the markets requires commitment and dedication to attain good crop management. Participation in crop farming improves the information about availability of important farm inputs such as improved technologies, current farming practices, increased crop harvesting, and decreased costs where possible (Zheng & Ma, 2023). Further, full participation in crop farming improves linkage between farmers and farm input dealers and extension officers. It helps farmers to choose the appropriate farm inputs, crop market networking, and good complementary agronomic technologies for their farming (Fischer & Qaim, 2012; Liu et al., 2020). Full participation is said to improve early detection of unusual situations such as diseases or insects on crops and timely inform the experts to recommend solutions (Gautam et al., 2017). Crop farming management goes beyond the farm; it reminds farmers to search for markets before harvesting. Rational farmers will search for higher price margins. Farmers search markets through various information source channels such as radio, TV, or the internet (Hao et al., 2018). ICT has improved crop management performance of smallholder household farmers in many places (Zheng & Ma, 2023). We employed covariates influencing on farm performance (Daudu et al., 2023; Fasakin et al., 2022; Lu & Ng, 2021; Manda & Alene, 2018; Zheng & Ma, 2023). The extant studies on youth participation in agriculture and their impacts on farm performance confirms that there is a linkage between youths' intensity of participation and farming performance.

To add to the nexus between agricultural performance and youths' intensity of participation, we have examined the crop yields, net returns, and returns on investment (ROI).

To this end, there is scanty empirical evidence in the extant literature. For better understanding, this paper presents an empirically investigation about the impact of youth intensity of participation on crop harvests, net returns, and ROI using data collected from maize youth farmers in Tanzania. We adopt the doubly robust IPWRA estimator from PSM in complement with "movestay" from ESR model. These models have been applied in several impact evaluation studies (Boye et al., 2024; Fasakin et al., 2022; Lu & Ng, 2021; Ma et al., 2022; Nikam et al., 2022; Zheng & Ma, 2023). The conceptual framework of the study is depicted in Figure 1.

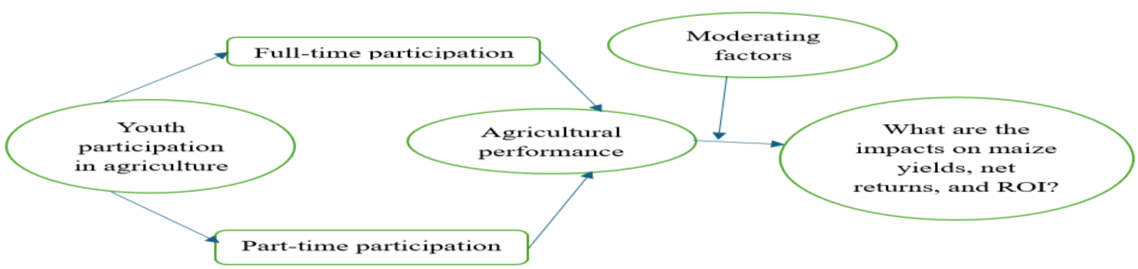

Figure 1. **Potential pathways of the impact of youth participation in agriculture**
Source: Authors, 2025

2.2. Empirical literature review

The youth's participation in agricultural activities has been well researched. Although most of the research findings about youth participation in agriculture focus on the youth's intention to participate in the agricultural sector. Several studies demonstrate that participation of youth in agriculture is desirable because youths are energetic, dynamic, and diverse social groups. Their aspirations in agriculture and their farm performance are modified by social transformation and experiences (Proctor & Lucchesi, 2012).

Youth's behaviour to participate in agricultural activities is complex and difficult to study. Numerous studies have examined youths' participation in agriculture, providing varying findings and location specific. For example, meta-analysis studies on youth participation in agriculture reveal that most studies hinge on youths' attitudes and perceptions of agricultural activity, the impact of training intervention programs to attract youth in the sector, contextual factors influencing youth buy-in in the sector, and challenges facing youth in the agricultural sector (Boye et al., 2024).

Some extant studies focus on youths' attitudes and perceptions such as intentions and career development in agriculture, desire to engage, level of interest, inclination, perceived gains, and agriculture is a rural activity for poor people (African Union, 2011; Baloyii et al., 2023; Cheteni et al., 2017; Haggblade et al., 2015; Irungu et al., 2015; Magagula & Tsvakirai, 2020; Mkong et al., 2021; Unity, Chifupa & Aluwani, 2021).

Other studies investigate the contextual factors influencing youth buy-in in agriculture. Factors such as access to credit, land, training programs, technology, socioeconomic status, and experiences from elders such as parents, household members, and friends who are participating in the sector (Akrong et al., 2020; Anyidoho et al., 2012; Bello et al., 2022; Tarekegn et al., 2022). If the interactions of the contextual factors give positive stimuli to youth, they will be motivated to engage in the sector. However, they get discouraged if they see no future in the sector (Kafle et al., 2019).

Furthermore, other studies focused on interventional skills training and farm programs and their associated impact of youth participation in the agricultural sector. They outline findings that youths engagement in the farm programs improves their income, technical skills, increase opportunities awareness, and poverty reduction (Adeyanju et al., 2021; Adeyanju et al., 2023; Giuliani et al., 2017; Inegbedion & Islam, 2021; Inegbedion & Islam, 2020; Ogunmodede et al., 2020; Uduji & Okolo-Obasi, 2022).

The extant literature highlights challenges faced by youth in the sector. The challenges include lack of agricultural finance, social bottlenecks, limited training, support, and land ownership. Youth and the agricultural sector face problems and challenges that are evolving over time (Bonnke et al., 2022; Geza et al., 2022; Gordillo & Prescott, 2023; Yeboah et al., 2020).

The recently emerging studies are providing some insights on the impact of youth participation in agriculture on crops such as beans and paddy harvests, and income. These studies confirm the positive relationship between youth participation in agricultural skills training and farm programs and crop productivity and income (Dooley & Schreckhise, 2016; Fasakin et al., 2022; Gordillo & Prescott, 2023; Kaki et al., 2022).

The limitations of the extant studies on youth participation in agricultural activities are that they heavily rely on determinants of youth participation in agricultural activities, challenges faced by youth in the sector, the willingness of youth to accept agriculture as a career, rising awareness of the sectors' potentials, and cognitive development of youth choosing agriculture as a first career option. The persistence youths' negligence about agriculture, indicates that there are contextual problems and challenge facing youths and the agricultural sector that require contextual interventions.

This may imply that researchers at this end know relatively little about the impact of youths' intensity of participation in agriculture on maize yields, net returns, and ROI. If stakeholders require a better understanding of the impact of youths' participation in agriculture on yields, net returns, and ROI and the factors related to their participation and crop farming performance, then examining how youths' intensity of participation in the sector impacts crop yields, net returns, and ROI is crucial.

This research, for example, examines how youth intensity engagement can bring full advantage in terms of augmenting yields, net returns, and ROI. This investigation contributes to the existing gap in the literature by identifying the determinants of youth intensity involvement in agriculture.

Also, the impact of youths' intensity of participation on maize yields, net returns, and ROI which is missing in the literature.

2.3. Models' specifications and the estimation techniques

We adopted PSM and ESR models to estimate the average treatment effect on the treated (ATT). The ATT provided the average difference in crop yields, net returns, and ROI between full-time and part-time participants. With reference to extant studies (Armel Nonvide, 2023; Boansi et al., 2024; Daudu et al., 2023; Fasakin et al., 2022; Giwu et al., 2024; Haryati et al., 2024; Lu & Ng, 2021; Nikam et al., 2022; Noltze et al., 2013) on impact evaluation, we calculated ATT as follows:

$$ATT = E\{Y_{iA} - Y_{iN} | T_i = 1\} = E(Y_{iA} | T_i = 1) - E(Y_{iN} | T_i = 1) \qquad (ii)$$

Where, $E\{.\}$ is expectation operator, Y_{iA} and Y_{iN} are outcomes (hereof maize yields, net returns, and ROI) for youths' intensity of participation for farmer i , respectively, T_i is a treatment as an indicator of intensity of participation status for farmer i (1 for higher-intensity, 0 for non-higher-intensity).

We can observe the outcome of higher intensity of participation such that

$E(Y_{iA} | T_i = 1)$

But we are not able to observe if had they not involved in the intensity of participation

$E(Y_{iN} | T_i = 1)$

The intensity of participation in agriculture is not randomly assigned, and the decision may be systematically between those with higher intensity of participation and non-higher intensity.

Thus, it is likely that self-selection bias into the estimated ATT. Also, we just use the observed outcomes for non-intensity (part-time) that is

$E(Y_{iN} | T_i = 0)$ to substitute the unobserved counterfactuals (Manda & Alene, 2018).

The empirical literature shows that there are several ways have been adopted to have the unobserved counterfactual and be able to get unbiased ATT (Wooldridge, 2010; Manda & Alene, 2018; Zheng & Ma, 2020). The most known methods in the impact evaluation studies in agriculture are ESR model and the PSM. The PSM consists of the estimators such as inverse probability weights (IPW) estimator, regression adjustment (RA) estimator, and IPWRA estimator (Lu & Ng, 2021; Ma et al., 2018, 2022; Manda & Alene, 2018; Zheng & Ma, 2023).

As we introduced that merely PSM approach is subjective to correct specification of the choice model, though even if the selection model correctly specified still the outcome model if is mis specified can lead to inconsistencies and biased estimates of the ATT (Wooldridge, 2010).

The doubly robust IPWRA can give us the unbiased estimates of ATT as is able to divide the choice and outcome equations such that the IPW estimator relies on the correct select (treatment) equation specifications while the RA estimator relies on the observed outcome equation correct specification (Ma et al., 2018).

Further, we use the ESR model in our estimation of ATT and the average treatment effect on the untreated (ATU). However, ESR does not directly provide the ATT. The ESR model depends on coefficient estimates (Zheng & Ma, 2023). It requires a post estimation step to get the average of the treatment for both participants and non-participants (Akter et al., 2022).

In comparison between ESR model and PSM-IPWRA, the IPWRA has a doubly robust check in nature (Lu & Ng, 2021; Manda & Alene, 2018; Zheng & Ma, 2023). However, the IPWRA can address selection bias issue emanating from observed factors only (Kang & Schafer, 2007)

IPWRA requires that either of the equations be correctly specified (either IPW for choice or RA for outcome equations), respectively (Wooldridge, 2010; Zheng & Ma, 2023). We adopt the IPWRA in our examination of the impact of youths' intensity participation in agriculture on farm performance.

We adopt the three stages of ATT estimates under the IPWRA estimator (Zheng & Ma, 2023) such that;

In stage one we calculate the IPW based the weight of the observations on the inverse probability of involvement in agricultural activities where we obtain the propensity scores (probability) of youths' intensities of participation in agriculture as in eqn. (iii) such that:

$$\boldsymbol{p}(x)\ Pr(T_i = 1|x) = F\{h(x)\} = E(T_i|x) \qquad (iii)$$

Where, $\boldsymbol{p}(x)$ is the probabilities of youth intensity involvement in agriculture. x refers to the series of vector of covariates (hereof; youth's background, socioeconomic status, institutional, and environmental factors) that influence the probability. $F\{.\}$ represents the cumulative distribution function. $h(x)$ is the determinant of youths' intensity of involvement in agriculture

In this stage, we adopt the logit model to estimate eqn. (iii). Then the probability (propensity scores) in eqn. (iii) to get the synthetic sample reflecting youths' intensity of participation in agriculture (Zheng & Ma, 2023).

Accordingly, assign 1 to the inverse weights of higher intensity youth participation and for non-participant we sign $\frac{\acute{P}(X)}{1-\acute{P}(X)}$ as presented in Manda & Alene (2018). These weights can be written as follows:

$$w_i = T_i + (1 - T_i)\frac{\acute{P}(X)}{1-\acute{P}(X)} \qquad (iv)$$

where $\acute{P}$ presents the probability (propensity scores) from stage 1

Secondly, we adopt from the extant empirical studies to run linear regression models for both youths' higher intensity participants and non-higher intensity participants in crop farming, respectively. Thus, the average treatment of the treated (ATT) for RA estimator on the outcome equation can be obtained by averaging the predicted outcome for higher/full intensity participants and non-intensity participants (Wooldridge, 2010; Manda & Alene, 2018; Zheng & Ma, 2023)

Thus, we express the RA estimator specification as here under:

$$ATT_{RA} = n_A^{-1}\sum_{i=1}^{n} T_i\ [r_A(X,\delta_A) - r_N(X,\delta_N)] \qquad (v)$$

Where n_A refers to the sample of the youths' participating in agriculture. $r_A(.)$ and $r_N(.)$ represent the regression models for both higher intensity participants and non-participants, respectively. X (Includes the observed covariates. δ_j is the correlated parameters such that $\delta_j = \propto_j, \beta_j,\ (j = A, N)$.

Lastly, we embark on a third stage by combining the eqns., (iv) for (selection equation: the IPW estimator) and (v) for (outcome equation: the RA estimator) to get the IPWRA estimator.

As previous studies present the IPWRA estimates being both consistent and unbiased bearing in mind that either of the two equations is correctly specified (select/choice eqn.: IPW or outcome eqn.: RA estimator) (Lu & Ng, 2021; Manda & Alene, 2018; Zheng & Ma, 2023).

To get the ATT from the combined IPWRA estimator, we specified eqn. (vi)

$$ATT_{IPWRA} = n_A^{-1} \sum_{i=1}^{n} T_i \left[r_A^*(X, \delta_A^*) - r_N^*(X, \delta_N^*)\right] \quad (vi)$$

Where $\delta_A^* = (\propto_A^*, \beta_A^*)$ and $\delta_N^* = (\propto_N^*, \beta_N^*)$ refers to the inverse probability weighted parameters, regressed from weighted regression steps for both adopters of higher intensity of participation and non-adopters, respectively.

Accordingly, we express both equations of adopters and non-adopters in eqns.(vii) and $(viii)$, respectively.

$$\min_{\propto_A^*, \beta_A^*} \sum_{i=1}^{n} w_i \; (Y_i - \propto_A^* - X\beta_A^*)^2 / \acute{P}(X, \hat{Y}) \quad (vii)$$

$$\min_{\propto_N^*, \beta_N^*} \sum_{i=1}^{n} (1 - w_i)\,(Y_i - \propto_N^* - X\beta_N^*)^2 / \left(1 - \acute{P}(X, \hat{Y})\right) \quad (viii)$$

As we introduced it earlier, we compute ATT under IPWRA using the weighted regression coefficients, where the weights are the estimated inverse probabilities of the treatment (Stata Press, 2019; Zheng & Ma, 2023). In this way the IPWRA estimator is doubly robust estimator.

The IPWRA estimates the unbiased ATT estimates using conditional-independence (CI) and overlap assumptions. CI assumes a rich set of observed covariates are controlled and used to randomly assign youth intensity of participation in agriculture while are uncorrelated with outcomes in eqn. (iii) (Wooldridge, 2010). The overlap assumption states that each youth farmer has a binding positive probability of crop farming through levels of participation conditional on the set of covariates. The overlap assumption ensures that non-intensity participants have similar covariates in the sample. The normalized differences of each covariate between youths' levels of participation in agriculture help to assess the overlap assumptions (Manda & Alene, 2018). In our analysis we compare the results from IPWRA with the estimates from ESR and PSM models.

3. Data and descriptive analysis

3.1. Data source and variables

This study used secondary data from the National Sample Census of Agriculture (NSCA) of 2020 of Tanzania. A National Master Sample of the National Bureau of Statistics and Office of the Chief Government Statistician as a framework for household-level surveys were adopted. The 2012 Population and Housing Census frame was used to get rural and urban enumerated areas (EAs) as Primary Sampling Units (PSUs) using probability proportionate to size (PPS). The survey randomly selected 33,808 agricultural farming households from EAs for data collection using structured questionnaires. The probability of being selected to participate was based on number of households.

To avoid bias in recalling the data from small farmers, the survey was conducted immediately after farming seasons. Also reported financial information about income and off-farm income were obtained by observing and recording the harvests in terms of kilograms and recording the harvest values reflecting the prevailing market prices. This paper collapsed the sample to 3399 youth across all climatic regions of the country. To meet the international standards that youth smallholder farmers are those who cultivate less than 2 (Acclassato et al., 2021; FAO, 2015; Lowder et al., 2021; Noltze et al., 2013; TNCFI, 2017).

The survey contains a series of questions that enable understanding youths' participation behaviour in agriculture. The question to understand the range of agricultural activities performed in the agricultural sector: *Question 2.1. Type of agricultural activities of the household involving*. Another question is to understand the main activity that youths do in the sector: *Question 3.11. What is the main activity of (NAME)?* The last question is to understand the youth intensity of participation in agriculture: *Question 3.1c10. How involved is (NAME) in farming activities?* These questions provide us a prior understanding of the relationship between youths' intensity of participation and crop farming performance.

In *qn. 2.1*, we strictly picked youths who are dealing with crops only. In *qn. 3.11*, we strictly picked youths who are dealing with crop farming. For simplicity, we picked youth farming maize. Maize is extensively cultivated as a staple food and business for the surplus harvests. Finally, in *qn. 3.1c10*, we sorted two groups of youths. Group one comprises only youths who are full-time working in their plots/farms summing up to 2562. Group two consists of part-time involvement in their plots/farms who totalling up to 837. Table 1 reports a summary of statistics and descriptions of the outcome variables and covariates.

Table 1. Variable definitions and summary of statistics

Variable	Descriptions	Mean	S. D
Treatment Variable			
Intensity of engagement	1 if higher intensity engagement in agriculture, 0 otherwise	.75	.43
Outcome variables			
Maize yields	Yields in kg/hectare	6.22	.61
Net returns	Total farm/plot revenue minus total cost incurred in Tanzania shillings (TZs).	11.98	1.05
ROI	Return on investment refers to a ratio of the net returns to the production cost.	1.46	1.69
Covariates			
age	Age of youth (years)	29.94	3.86
gender	1 if youth is a male, 0 otherwise	.86	.35
General education	1 if youth have formal education, 0 otherwise	.21	.41
No formal education	1 if youth have no formal education, 0 otherwise.	.15	.36
Household size	Number of family members (persons)	4.51	2.03
Access to agricultural credit	1 if youth accessed agricultural credit, 0 otherwise.	.044	.21
Member in Cooperative	1 if youth is a member of a farmers' cooperative, 0 otherwise	.04	.19
Member in an organization	1 if youth is a member of a farmers' organization, 0 otherwise	.02	.15
Access to extension services	1 if youth accessed extension services, 0 otherwise	.08	.27
Distance to the market	Distance to the nearest market in km	10.62	9.84
Distance to the farm	Distance to the plot/farm in km	4.56	2.64
Off-farm income	1 if youth have another income-generating job, 0 otherwise	.53	.5
Farm/plot size	Plot/farm size in hectares (planted maize)	1.07	.59
Irrigation	1 if youth used irrigation in a plot/farm, 0 otherwise	.07	.25

Used tractor	1 if youth used a tractor in a plot/farm, 0 otherwise	.37	.48
Improved Seeds	1 if youth used improved seeds in a plot/farm, 0 otherwise	.19	.39
Information source channels	1 if youth used radio, phones, or the internet to acquire agricultural information, 0 otherwise	.13	.34
Past drought	1 if youth experienced drought, 0 otherwise	.33	.47
Humid	1 if youth located in humid regions, 0 otherwise	.04	.2
Tropical cool (subhumid)	1 if youth reside in tropical cool (subhumid) regions, 0 otherwise	.42	.49
Tropical warm (subhumid)	1 if youth reside in tropical warm (subhumid) regions, 0 otherwise	.38	.49
Semiarid	1 if youth located in semiarid regions, 0 otherwise	.13	.33

Source: NCSA of Tanzania 2020

3.2. Descriptive statistics

Table 2 informs the mean differences of outcome variables among youths participating in crop farming. At least the results clearly indicate that the maize net returns and ROI for farmers intensively involved in agriculture are higher than their counterparts. The two outcomes are positive and statistically significant, explaining the difference between higher-intensity participants and non-higher participants. Surprisingly, youths under low intensity of participation harvest more than higher intensity participants. The implication of these results is that non-adopters harvest more of gross maize yields under higher expenses. This is not economically viable, as they get fewer net returns and ROI. The differences offer preliminary evidence that youths' levels of participation differ in their effects on farm performance. Although the mean differences here are statistically significant, they should not be fully used to explain the nexus between youth levels of participation in agriculture and their impact on farm performance. They do not take into consideration the potential selection bias.

Table 2. Mean differences of outcome variables between full-time participants and non-participants

Outcome variables	Full-time participants	Non-participants	Mean differences
Maize Yields	6.204	6.274	-.071***

Net returns	11.995	11.914	.082*
ROI	1.613	.996	.617***
Sample size	2562	837	.

Standard errors are in parentheses. *** *p<.01, and * p<.1* (significance at the 1%, and 10% levels, respectively)

Source: NCSA of Tanzania 2020

Table 3 depicts the systematic differences between youth involved in crop farming as covariates explaining their status of agricultural participation. Column 4 shows the mean difference. The observed differences in the status of farmers may imply that farmers self-select themselves to be intensive participants and non-intensive participants.

Further, Table 3 presents the normalized differences of farmers characteristics between higher intensity participants and non-higher intensity participants. As highlighted in the extant literature (Manda & Alene, 2018; Zheng & Ma, 2023), the normalized differences aid the assessment of overlap assumptions. It is advisable to consider the normalized values that exceed the threshold value of 0.25 (Zheng & Ma, 2023). Column 5 reports that most values do not exceed the threshold value of 0.25 except the tropical cool and warm, guaranteeing the validity of the IPWRA estimator we specified in eqn. (vi).

Table 3. Differences of the characteristics between full-time participants and non-participants

Covariates	Full-time participants	Non-participants	Mean differences	Normalized differences
age	29.933	29.942	-.01	-.001
gender	0.859	.86	-.002	-.002
General education	0.156	.381	-.225***	-.225
No formal education	0.170	.087	.083***	.083
Household size	4.603	4.24	.362***	.017
Access to agricultural credit	0.049	.031	.018**	.018
Member in Cooperative	0.042	.021	.022***	.022
Member in an organization	0.026	.022	.004	.004
Access to extension services	0.078	.092	-.014	-.014
Distance to the market	11.046	9.295	1.75***	.053
Distance to the farm	4.473	4.816	-.344***	-.023
Off-farm income	0.433	.827	-.393***	-.393
Fram/plot size	1.076	1.049	.026	.013
Irrigation	0.071	.064	.007	.007
Used tractor	0.357	.424	-.067***	-.067
Improved Seeds	0.197	.178	.018	.018

Information source channels	0.128	.144	-.017	-.017
Past drought	0.338	.319	.019	.019
Humid	0.046	.034	.013	.013
Tropical cool (subhumid)	0.410	.438	-.028	.438
Tropical warm (subhumid)	0.395	.337	.058***	.337
Semiarid	0.111	.176	-.065***	-.065

Standard errors are in parentheses. *** *p<.01,* ** *p<.05,* * *p<.1* (significance at the 1%, 5%, and 10% levels, respectively)

Source: NCSA of Tanzania 2020

4. Regression results and discussion

4.1. Logit model of propensity score estimation

Table 4 reports the logit model regression results of youth participation in crop farming. It is difficult to interpret coefficients for this matter we calculate the marginal effects as appear in column 3. We further calculate the summary statistics for the whole model such that pseudo-R square is 0.169 and 75% of the whole model is correctly specified. The model χ^2 is 639.535, with a p-value of 0.000, and still proposes that the study model is statistically significant. The covariates in this study jointly and significantly explain farmers' decision to be involved in agriculture.

The results reveal that gender, general education, no formal education, household size, agricultural credit, membership in a farmers' cooperative, distance to the nearest market, off-farm income, access to irrigation, and use of farm machines such as tractors, experienced past drought, and being in tropical cool and semiarid areas are statistically significantly correlated with youths' levels of participation in agriculture.

The gender variable exerts a positive and statistically significant impact on involvement in agricultural activities, which indicates that being a young male is related to involvement in crop farming. The variable education exerts a negative impact on youth involvement in agriculture. As youths get more education, they increase the chance of being hired in other sectors, whereas youth with no formal education are statistically significantly related to intensive involvement in agriculture. Low or no formal education leaves youth with limited possibilities to seek jobs in other sectors. They have a high propensity to engage in agriculture. The sector absorbs both

skilled and unskilled individuals. The findings in this paper are in line with the extant findings that education may influence youth engagement in the sector and make them good farmers of today and tomorrow (Haryati et al., 2024; Ogunmodede et al., 2020). Youth with off-farm income-generating jobs lower their propensity to involve in agriculture. It is negative and statistically significant impact youth participation in agriculture.
Use of farm machines such as tractors indicates a negative statistically significant influence on youth participation in agricultural activities. In Tanzania, may imply that those who own them use them for hire and use the money to invest in agriculture. Use of tractors may increase the cost of production. It is crucial for expansion of investment in agriculture. Also, youth residing in tropical-cool and semiarid areas exert a negative and statistically significant impact on youth participation in agriculture.

Access to agricultural credit is a positive and statistically significant impact youth participation in agriculture. Credits enable youth to expand their farm operations and make easily acquire farm inputs. Credit enhances farm management and increases resilience in adverse climatic conditions (Amadu et al., 2020). Credit improves crop farming performance and attracts youth engagement in agriculture because it eases farm management while augmenting crops and income for those who are able to access it (Geza et al., 2021).

Being a member of a farmers' cooperative increases the propensity to engage in agricultural activities. Cooperatives enhance members with farm input support such as seeds and pesticides. Storage and market searching have been easier under the cooperative or union. Farmers under unions find it easy for them to search for assistance from the government, and they form strong bonds for crop price bargaining power. The findings concur with the findings of Giwu et al. (2024), who found that membership in a farmer organization increases propensity to engage in agricultural activities.

Access to irrigation facilities attracts youth in the sector. Irrigation is positive and statistically significant, influencing youth participation in agriculture. Irrigation facilities ensure crop farming performance throughout the farming season, especially in the uncertain temperature, humidity, and precipitation variation. Irrigation is reported to impact youth engagement and improve on farm performance in many places (Chipfupa & Tagwi, 2021).

Distance to the nearest market is positive and statistically significant, influencing youth participation in agriculture. Farmers get farm inputs and send their harvests to the market. Being near to market offers advantages such as reducing transport costs, saving time wastage, easing access to farm inputs, providing agricultural information access, and updating crop market prices. These are crucial attributes that attract youth involvement in the sector (Mthi et al., 2021). Further, household size is a positive and statistically significant factor, increasing the propensity to engage in agricultural activities. Many persons in a household may mean a supply of labour or a high dependency ratio. Youth are obliged to engage in agriculture because it is a source of food and other obligations. The results in this study concur with other findings in other studies. They found that household size determines the involvement of youth in agricultural activities (Akrong et al., 2020; Ma et al., 2022).

Table 4. Determinants of participation on crop farming (maize): Logit model estimates

Variables	Coefficients (SE)	Marginal effects
Age	-.008 (.012)	-0.001
Gender	.234 (.131)*	0.038*
General education	-.963 (.101)***	-0.175***
No formal education	.458 (.15)***	0.065***
Household size	.052 (.025)**	0.008**
Access to agricultural credit	.615 (.242)**	0.080***
Member in Cooperative	.757 (.291)***	0.094***
Member in an organization	.293 (.303)	0.042
Access to extension services	.08 (.161)	0.012
Distance to the market	.019 (.005)***	0.003***
Distance to the farm	-.024 (.017)	-0.004
Off-farm income	-1.745 (.105)***	-0.266***
Fram/plot size	.061 (.079)	0.009
Irrigation	.289 (.182)	0.042*
Used tractor	-.243 (.099)**	-0.039**
Improved Seeds	.141 (.115)	0.022
Information source channels	.017 (.134)	0.003
Past drought	.183 (.096)*	0.028*
Humid	-.498 (.395)	-0.089
Tropical cool (subhumid)	-.655 (.317)**	-0.106**

Tropical warm (subhumid)		-.3 (.317)	-0.048
Semiarid		-1.171 (.332)***	-0.229***
Constant		2.606 (.509)***	
Summary statistics			
Mean dependent var	0.753	SD dependent var	0.431
Pseudo r-squared	0.169	Number of obs	3387
Chi-square	639.535	Prob > chi2	0.000
Akaike crit. (AIC)	3189.688	Bayesian crit. (BIC)	3330.625
Log likelihood	-1571.84		

Standard errors are in parentheses. *** *p<.01,* ** *p<.05,* * *p<.1* (significance at the 1%, 5%, and 10% levels, respectively)

Source: NCSA of Tanzania 2020

4.2 Impact of youths' intensity of participation on farm performance

Table 5 presents the ATT estimates for maize yields, net returns, and ROI. The ATT estimates were obtained by using IPWRA estimator. The estimates report that youths' levels of involvement in agriculture have a positive and statistically significant impact on outcomes, only that the impact on yields is positive but not statistically significant. As we noted earlier, non-intensive participants might be getting more gross maize yields at very high costs of production. They are getting fewer net returns and ROI. Further, youths' intensity of participation gains an average of 4.07% net returns higher than their counterparts. A study investigated the impact of the intensity of involvement in a farming program. Their findings confirmed that higher intensity improved revenue and net returns more than their counterparts (Fasakin et al., 2022). Intensive involvement in agriculture increased returns on investment by 9.5% compared to those youth who are partially involved in maize farming. As we noted earlier, the ROI is rarely discussed in the extant studies. However, understanding the net returns, costs, and investment returns resulting from agricultural production is essential.

Table 5. Average treatment effects of intensity engagement in crop farming on outcome variables: IPWRA estimator

Outcome variables	Full-time participants	Non-participants	ATT (SE)	% change
Maize Yields	5.76 (.06)	5.62 (.115)	.13 (.12)	2.31
Net returns	10.45 (.14)	10.31 (.242)	.42 (.25) *	4.07
ROI	1.15 (.05)	1.05 (.1)	.1 (.1) ***	9.5
Sample size	2562	837		

ATT refers to average treatment effects on the treated. Robust standard errors are in parentheses.
**** p<.05, * p<.1* (1% and 10% levels, respectively)
Source: NCSA of Tanzania 2020

Results in Table 6 and Table 7 are for comparison. As noted earlier, the ESR model had an absolute advantage compared to PSM. The extant studies on impact evaluation indicate that, PSM tackles selection bias from observed variables. In contrast, the ESR model can address bias from observed and unobserved variables (Kang & Schafer, 2007; Lu & Ng, 2021; Manda & Alene, 2018; Zheng & Ma, 2023). Only the ATT estimates of the ESR and PSM models are presented and discussed in this paper for simplicity.

Table 6 reports the PSM results. With consideration of the weakness of PSM that, it requires correct specification, the results are somehow reflecting the IPWRA results as a doubly robust estimator. The results still confirm that intensity involvement in agriculture outweighs the partial involvement. All outcomes are significant at 1% such that the average maize productivity of intensity participants is 3.04%, net returns are 8.83%, and ROI is about 52.33% compared to their counterparts.

Table 6. Average treatment effects of youths' intensity of participation in crop farming on outcome variables: PSM model results

Outcome variables	Full-time participants	Non-participants	ATT (SE)	% change
PSM model estimates				
Maize Yields	5.76 (.03)	5.59 (.03)	.17(.13)***	3.04
Net returns	10.73(.075)	9.9(.076)	.83(.11)***	8.83
ROI	1.32(.033)	.86(.025)	.45(.04)***	52.33
Sample Size	2562	837	.	.

Note: Average treatment effects on the treated (ATT). Robust standard error (SE). The PSM results are from the nearest neighbour matching (nnmatch) approach. Among the 2562 treated samples (full-time participants), 38 are off support in the nnm estimations; among the 837-control group (partial participants), 0 are off support in the nnm estimations. *** (indicates significance at the 1% level)
Source: NCSA of Tanzania 2020

For clear understanding, we add graphic illustration of common support as important assumption of PSM. Common support guarantees that, in both groups, there are youths that can be matched.

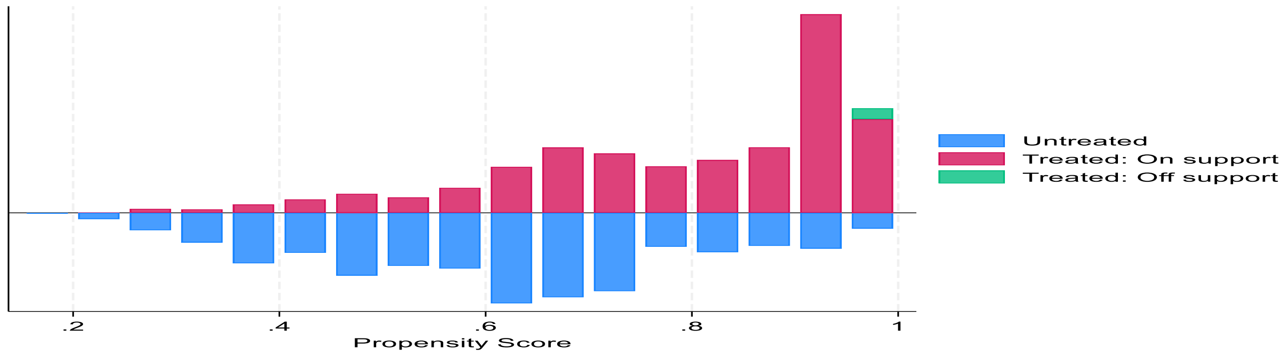

Figure 2. **Graph for common support for treated and untreated groups of farmers**
Source: NCSA of Tanzania 2020

Table 7 shows the ESR estimates. Just like in IPWRA and PSM results, the ATTs indicate that youths' intensity of participation impacts farm performance. Intensity participants outweigh their counterparts. For instance, in maize productivity higher-intensity adopters get 3.85% higher than non-intensity participants. Likewise, for net returns, intensity participants offer 1.1% higher than their counterparts. The ATT for ROI, the intensity participants get 31.96% less than their counterparts. I f had they involved intensively would have gained 25%.

Additionally, we report the average treatment effect on the untreated (ATU) in Table 7 for each outcome. We respond to the assumption that what if had they involved intensively in agriculture? What would be their gains from crop yields, net returns, and ROI? The ATUs report that they would have gained significantly. On maize, they would have gained 23.6% and for net returns they would have gained 20.15%. ATUs for this study tell us that a higher intensity of involvement in agriculture is crucial for farm performance and economic growth through augmenting crop yields, net returns, and ROI.

Table 7. Average treatment effects of youths' intensity of participation in crop farming on outcome variables: ESR model results

Outcome variables	Effect	Full-time participants	Non-participants	Diff (SE)	% change
Maize Yields	ATT	6.2(.002)	5.97(.004)	.23(.004)***	3.85
	ATU	7.75(.004)	6.27(.006)	1.48(.009)***	23.6
Net returns	ATT	11.99(.011)	11.86(.019)	.13(.022)***	1.1
	ATU	14.74(.016)	11.91(.023)	2.4(.03)***	20.15

ROI	ATT	1.32(.007)	1.94(.014)	-.62(.014)***	31.96
	ATU	1(.007)	.8(.012)	.2(.013)***	25
Sample size		2562	837		

Robust standard errors are in parentheses. p<.1***(indicates significance at the 1% levels)
Source: NCSA of Tanzania 2020

5. Conclusions and policy implications

Youth are advantageous in terms of physical fitness, energy efficiency, quick adoption of new skills and technology use, and dynamic and diverse social groups. Their deliberate involvement in agriculture can significantly transform the sector from merely a food source to a commercial-based sector. Their involvement in agriculture is potential for livelihoods and economic performance. However, initiatives have not won youth buy-in in agriculture and their impact of intensity of participation in the sector is scanty.

This paper examines the impact of youths' intense engagement in agriculture on maize yields, net returns, and returns on investment (ROI). We adopted a doubly robust IPWRA estimator backed by PSM and ESR models.

The empirical results revealed the factors that influence youths' participation in agriculture. The results showed that factors such as gender (male), no formal education, household size, agricultural credit, membership in a farmers' cooperative, distance to the nearest market, access to irrigation facilities, and experience of past droughts are positive and statistically significant, associated with youths' intensity of participation in the sector. In contrast, general education, off-farm income, and living in tropical cool, and semiarid areas are negatively and statistically significantly reducing the propensity to intensively engage in agriculture.

The ATT of the intensity of participation on maize for net returns is 4.07%, and for ROI is 9.5%. The positive impacts of the intensity of involvement on net returns and ROI are triggered by cost effects. Additionally, the complementary models of PSM and ESR results largely concur with the IPWRA results.

The results in this paper have policy, academic, and practical implications. First, our findings of positive and negative factors significantly influence youths' levels of participation in agriculture. Also, the positive impact on maize yields, net returns, and ROI highlights important insights to stakeholders should ensure strategic integration of youth in the sector while minding the cost of production.

Second, the novelty of the study is meant to contribute to the literature, as there are scant studies on the impact of youth on net returns and ROI. These findings can serve as references in the subsequent studies in the area.

Third, to the elders and youths, our findings reveal the potential of agriculture on the returns on investment. Both have evidence that there is a payoff from investment in agriculture and youths, intensity of participation has meaningful implications for crop farming rather than partial participation, which is associated with more expenses.

This paper encounters few limitations emanating from data and scope. First, we use cross-section data, which are limited to capture time-variant factors that might have affected our findings. The same study can be carried out in the future using panel data. Secondly, data are only limited to Tanzania. To have a generalized understanding of the effects of youth involvement in agriculture on net returns and ROI, a cross-country study on the same is important.

6. Declarations

Author contribution statement

Yohane Kitwima Magembe: Comprehended and designed the study; analyzed and interpreted the data, materials, analysis tools, and writing the paper. Martin Bai: Proofreading, editing, grammar, and setup.

Funding statement

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Ethical declaration

This paper uses secondary data. At the time of data collection, clearance and permission from relevant authorities and informed consent from respondents were seriously adhered to.

Data availability statement

Data is available from NBS as NSCA 2019/20 with Ref. TZA-NBS-NSCA-2019-v01. The data can be downloaded from [https://www.nbs.go.tz/tnada]. The data used in this paper were downloaded on 20/05/2023.

Competing Interest

We declare no known competing interests.

Additional information

No extra information is available for this paper at present.

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References

Kidane, A., Hepelwa, A., Tingum, E., & T. W. H. (2013). *Agricultural Inputs and Efficiency in Tanzania Small Scale Agriculture: A Comparative Analysis of Tobacco and Selected Food Crops*. *3*, 1–13.

Acclassato, D., Goudjo, G. G., & Senou, M. M. (2021). Access to finance and difference in family farm productivity in Benin: Evidence from small farms. *Scientific African*, *13*, e00940. https://doi.org/10.1016/j.sciaf.2021.e00940

Adeyanju, D. F., Akomolafe, K. J., Mburu, J. I., Evelyn, O., Adebayo, S. A., Joy, C., Adeyanju, D. F., Akomolafe, K. J., & Mburu, J. I. (2023). Does entrepreneurship improve the livelihood of young people ? Evidence from the NDE program beneficiaries in Kano state , Nigeria Does entrepreneurship improve the livelihood of young people ? Evidence from the NDE program beneficiaries in Kano state , N. *Cogent Business & Management*, *10*(2). https://doi.org/10.1080/23311975.2023.2248735

Adeyanju, D., Mburu, J., & Mignouna, D. (2021). *Youth Agricultural Entrepreneurship : Assessing the Impact of Agricultural Training Programmes on Performance*. 1–11.

African Development Bank (AfDB). (2016). *Jobs for Youth in Africa. Retrieved from. https://www.afdb.org/fileadmin/uploads/afdb/Images/high_5s/Job_youth_Africa_Job_youth_Africa.pdf.* (pp. 1–2).

African Union. (2011). African Youth Decade 2009-2018 Plan of Action. *Resources | Youth and the African Union Commission*, *May*, 17. http://africa-youth.org/sites/default/files/African Youth Decade Plan of Action 2009-2018 (English).pdf

Akrong, R., Mbogoh, S. G., & Irungu, P. (2020). Youth agripreneurship in the horticultural value-chain: The case of small-scale mango farmers in Southern Ghana. *African Development Review*, *32*(S1), S68–S77. https://doi.org/10.1111/1467-8268.12483

Akter, A., Geng, X., Endelani, G., Lu, H., Hoque, F., Kiraru, M., & Abbas, Q. (2022). Climate Risk Management Income and yield effects of climate-smart agriculture (CSA) adoption in flood prone areas of Bangladesh : Farm level evidence. *Climate Risk Management*, *37*, 100455. https://doi.org/10.1016/j.crm.2022.100455

Amadu, F. O., McNamara, P. E., & Miller, D. C. (2020). Yield effects of climate-smart agriculture aid investment in southern Malawi. *Food Policy*, *92*(January 2019), 101869. https://doi.org/10.1016/j.foodpol.2020.101869

Anyidoho, N. A., Leavy, J., & Asenso-okyere, K. (2012). Perceptions and Aspirations: A Case Study of Young People in Ghana's Cocoa Sector. *Published by Blackwell Publishing Ltd, 9600 Garsington Road, Oxford OX4 2DQ, UK and 350 Main Street, Malden, MA 02148, USA*, *43*(6).

Armel Nonvide, G. M. (2023). Impact of information and communication technologies on agricultural households' welfare in Benin. *Telecommunications Policy*, *47*(6), 1–10. https://doi.org/10.1016/j.telpol.2023.102570

Awotide, B. A., Karimov, A. A., & Diagne, A. (2016). Agricultural technology adoption, commercialization and smallholder rice farmers' welfare in rural Nigeria. *Agricultural and Food Economics*, *4*(1). https://doi.org/10.1186/s40100-016-0047-8

Baloyii, R., Wale, E., & Chipfupa, U. (2023). Rural youth interest in economic activities along the agricultural value chain: empirical evidence from Kwazulu-Natal (South Africa) and implications. *International Food and Agribusiness Management Review*, *26*(1), 49–65. https://doi.org/10.22434/IFAMR2021.0036

Bello, L. O., Baiyegunhi, L. J. S., Danso-Abbeam, G., Ogunniyi, A. I., Olagunju, K., Abdoulaye, T., Manyong, V., Bamba, Z., & Awotide, B. A. (2022). Assessing the Impact of Youth-in-Agribusiness Program on Poverty and Vulnerability to Poverty in Nigeria. *Agriculture (Switzerland)*, *12*(5), 1–14. https://doi.org/10.3390/AGRICULTURE12050735

Boansi, D., Gyasi, M., Nuamah, S., Tham-Agyekum, E. K., Ankuyi, F., Frimpong, R., Gbafah, A., & Gyan, C. B. (2024). Impact of agricultural credit on productivity, cost and returns from cocoa production in Ghana. *Cogent Economics and Finance*, *12*(1). https://doi.org/10.1080/23322039.2024.2402035

Bonnke, S. M., Martin, P., Nguezet, D., Nyamugira, A., Jean-jacques, M. S., & Manyong, V. (2022). *Farmers ' credit access in the Democratic Republic of Congo : Empirical evidence from youth tomato farmers in Ruzizi plain in South Kivu Farmers ' credit access in the Democratic Republic of Congo : Empirical evidence from youth tomato farmers in Ruzizi p*. *May*. https://doi.org/10.1080/23322039.2022.2071386

Boye, M., Ghafoor, A., Wudil, A. H., Usman, M., Prus, P., Feh, A., & Sass, R. (2024). *Youth Engagement in Agribusiness : Perception , Constraints , and Skill Training Interventions in Africa : A Systematic Review*.

Chakrabarti, S. (2018). *"The Youth Advantage: Engaging young people in green growth." IFAD Advantage Series. Rome: IFAD.* (p. 33).

Cheteni, P., Municipality, D., & Africa, S. (2017). *Youth Participation in Agriculture in the Nkonkobe District Municipality , South Africa Youth Participation in Agriculture in the Nkonkobe*. *9274*. https://doi.org/10.1080/09709274.2016.11907025

Chifupa, U., & Talgwi, A,. (2021). Youth ' s participation in agriculture : A fallacy or achievable possibility ? Evidence from rural South Africa. *South African Journal of Economic and Management Sciences*, *24*(1), a4004. https://doi.org/https://doi.org/ 10.4102/sajems.v24i1.4004

Daudu, A. K., Abdoulaye, T., Bamba, Z., Shuaib, S. B., & Awotide, B. A. (2023). Heliyon Does youth participation in the farming program impact farm productivity and household welfare ? Evidence from Nigeria. *Heliyon*, *9*(4), e15313. https://doi.org/10.1016/j.heliyon.2023.e15313

Diao, X., Hazell, P., & Thurlow, J. (2010). The Role of Agriculture in African Development. *World Development*, *38*(10), 1375–1383. https://doi.org/10.1016/j.worlddev.2009.06.011

Dooley, T. P., & Schreckhise, W. D. (2016). Evaluating Social Cognitive Theory in Action: An Assessment of the Youth Development Program's Impact on Secondary Student Retention in Selected Mississippi Delta Communities. *Youth and Society*, *48*(3), 383–401. https://doi.org/10.1177/0044118X13493445

Evodius Rutta. (2012). Current and Emerging Youth Policies and Initiatives with a Special Focus and links to Agriculture Tanzania (Mainland) Case Study Draft Report April 2012. *Food, Agriculture and Natural Resources Policy Analysis Network "FANRPAN," April*, 1–38.

FAO. (2015). *The economic lives of smallholder farmers* (p. 48).

Fasakin, I. J., Ogunniyi, A. I., Bello, L. O., Mignouna, D., Adeoti, R., Bamba, Z., Abdoulaye, T., & Awotide, B. A. (2022). *Impact of Intensive Youth Participation in Agriculture on Rural Households ' Revenue : Evidence from Rice Farming Households in Nigeria*.

Fischer, E., & Qaim, M. (2012). Linking Smallholders to Markets: Determinants and Impacts of Farmer Collective Action in Kenya. *World Development*, *40*(6), 1255–1268. https://doi.org/10.1016/j.worlddev.2011.11.018

Gautam, S., Schreinemachers, P., Uddin, M. N., & Srinivasan, R. (2017). Impact of training vegetable farmers in Bangladesh in integrated pest management (IPM). *Crop Protection*, *102*, 161–169. https://doi.org/10.1016/j.cropro.2017.08.022

Geza, W., Ngidi, M., Ojo, T., Adetoro, A. A., Slotow, R., & Mabhaudhi, T. (2021). Youth participation in agriculture: A scoping review. *Sustainability (Switzerland)*, *13*(16), 1–15. https://doi.org/10.3390/su13169120

Geza, W., Ngidi, M. S. C., Slotow, R., & Mabhaudhi, T. (2022). The Dynamics of Youth Employment and Empowerment in Agriculture and Rural Development in South Africa: A Scoping Review. *Sustainability (Switzerland)*, *14*(9). https://doi.org/10.3390/su14095041

Giuliani, A., Mengel, S., Paisley, C., Perkins, N., Flink, I., Oliveros, O., & Wongtschowski, M. (2017). Realities, perceptions, challenges and aspirations of rural youth in dryland agriculture in the Midelt Province, Morocco. *Sustainability (Switzerland)*, *9*(6). https://doi.org/10.3390/su9060871

Giwu, O., Mdoda, L., & Ntlanga, S. S. (2024). Assessing the socio-economic impact of youth engagement in agricultural enterprise for employment creation and poverty alleviation. *Cogent Social Sciences*, *10*(1). https://doi.org/10.1080/23311886.2024.2368097

Gordillo, P., & Prescott, M. P. (2023). *Cooking and Food Skills Interventions*.

Grace Inegbedion & Md. Mofakkarul Islam. (2021). Willingness and Motivation of Nigerian

Youth to Pursue Agricultural Careers after Graduation. *International Journal of Agricultural Science, Research and Technology in Extension and Education Systems (IJASRT in EESs)*, *11*(1), 55–69.

Haggblade, S., Chapoto, A., Drame-Yayé, A., Hendriks, S. L., Kabwe, S., Minde, I., Mugisha, J., & Terblanche, S. (2015). Motivating and preparing African youth for successful careers in agribusiness. *Journal of Agribusiness in Developing and Emerging Economies*, *5*(2), 170–189. https://doi.org/10.1108/jadee-01-2015-0001

Haji Athumani Msangi, Betty Waized, Daniel Wilson Ndyetabula, V. M. M. (2024). Heliyon Promoting youth engagement in agriculture through land titling programs : Evidence from Tanzania. *Heliyon*, *10*(7), e29074. https://doi.org/10.1016/j.heliyon.2024.e29074

Hao, J., Bijman, J., Gardebroek, C., Heerink, N., Heijman, W., & Huo, X. (2018). Cooperative membership and farmers' choice of marketing channels – Evidence from apple farmers in Shaanxi and Shandong Provinces, China. *Food Policy*, *74*(December 2017), 53–64. https://doi.org/10.1016/j.foodpol.2017.11.004

Haryati, N., Lasitya, D. S., Nurirrozak, M. Z., Febry, D., Fibrianingtyas, A., Rohman, A. R., & Hidayat, T. (2024). Demographics and course choices : impact on youth farming intention in Indonesia. *International Journal of Adolescence and Youth*, *29*(1). https://doi.org/10.1080/02673843.2024.2358088

Inegbedion, G., & Islam, M. M. (2020). Youth motivations to study agriculture in tertiary institutions. *Journal of Agricultural Education and Extension*, *26*(5), 497–512. https://doi.org/10.1080/1389224X.2020.1773285

International Fund for Agricultural Development (IFAD). (2019). *The Narrative on Rural Youth and Economic Opportunities in Africa: Facts, Myths and Gaps. https://www.ifad.org/documents/38714170/41187395/21_MabisoþandþBenfica_2019þRDRþ BACKGROUNDþPAPER.pdf/f741a15a-49c1-93ae-5155-5b0ef7bdf733.*

Irungu, K. R. G., Mbugua, D., & Muia, J. (2015). Information and Communication Technologies (ICTs) Attract Youth into Profitable Agriculture in Kenya. *East African Agricultural and Forestry Journal*, *81*(1), 24–33. https://doi.org/10.1080/00128325.2015.1040645

Jeffrey M. Wooldridge. (2010). *Econometric Analysis of Cross Section and Panel Data. The MIT Press Cambridge, Massachusetts London, England* (pp. 1–741).

Kafle, K., Paliwal, N., & Benfica, R. (2019). Who Works in Agriculture? Exploring the Dynamics of Youth Involvement in the Agri-Food Systems of Tanzania and Malawi. In *SSRN Electronic Journal* (Issue June). https://doi.org/10.2139/ssrn.3366984

Kaki, R. S., Mignouna, D. B., Aoudji, A. K. N., Adéoti, R., Kaki, R. S., Mignouna, D. B., Aoudji, A. K. N., Adéoti, R., & Kaki, R. S. (2022). *Entrepreneurial Intention among Undergraduate Agricultural Students in the Republic of Benin Entrepreneurial Intention among Undergraduate Agricultural Students in the Republic of Benin*. https://doi.org/10.1080/15228916.2022.2031584

Kang, J. D. Y., & Schafer, J. L. (2007). *Demystifying Double Robustness : A Comparison of Alternative Strategies for Estimating a Population Mean from Incomplete Data 1*. *22*(4), 523–539. https://doi.org/10.1214/07-STS227

Lindsjö, K., Djurfeldt, A. A., Isinika, A. C., & Msuya, E. (2020). Youths' participation in agricultural intensification in Tanzania. *AIMS Agriculture and Food*, *5*(4), 681–699. https://doi.org/10.3934/agrfood.2020.4.681

Liu, R., Gao, Z., Nayga, R. M., Shi, L., Oxley, L., & Ma, H. (2020). Can "green food" certification achieve both sustainable practices and economic benefits in a transitional economy? The case of kiwifruit growers in Henan Province, China. *Agribusiness*, *36*(4), 675–692. https://doi.org/10.1002/agr.21641

Lowder, S. K., Sánchez, M. V., & Bertini, R. (2021). Which farms feed the world and has farmland become more concentrated? *World Development*, *142*, 105455. https://doi.org/10.1016/j.worlddev.2021.105455

Lu, W., & Ng, J. N. (2021). *Impact of improved rice varieties on household food security in Northern Ghana : A doubly robust analysis*. *November 2020*, 342–359. https://doi.org/10.1002/jid.3525

Ma, W., Abdul-Rahaman, A., & Issahaku, G. (2022). Welfare implications of participating in agri-value chains among vegetable farmers in Northern Ghana. *Agribusiness*, *39*(3), 1–19. https://doi.org/10.1002/agr.21792

Ma, W., Renwick, A., & Bicknell, K. (2018). *Higher Intensity , Higher Profit ? Empirical Evidence from Dairy Farming in New Zealand*. https://doi.org/10.1111/j.1467-6419.2007.00503.x

Magagula, B., & Tsvakirai, C. Z. (2020). Development in Practice Youth perceptions of agriculture : influence of cognitive processes on participation in agripreneurship. *Development in Practice*, *30*(2), 234–243. https://doi.org/10.1080/09614524.2019.1670138

Maiga, E. W. H. (2016). Determinants of changes in youth and women agricultural labor participation in selected African countries. *Agricultural & Applied Economics Association Annual Meeting*, 1–18.

Manda, J., & Alene, A. D. (2018). *Impact of improved maize varieties on food security in Eastern Zambia : A doubly robust analysis*. 1–20. https://doi.org/10.1111/rode.12516

Miho, A. (2018). Comparing technical efficiency of maize smallholder farmers in Tabora and Ruvuma regions of Tanzania: a frontier production approach. *Asian Journal of Agriculture and Rural Development*, *7*(9), 180–197. https://doi.org/10.18488/journal.1005/2017.7.9/1005.9.180.197

Mkong, C. J., Abdoulaye, T., Dontsop-Nguezet, P. M., Bamba, Z., Manyong, V., & Shu, G. (2021). Determinant of university students' choices and preferences of agricultural sub-sector engagement in cameroon. *Sustainability (Switzerland)*, *13*(12), 1–18. https://doi.org/10.3390/su13126564

Morsy, H., & Mukasa, A. N. (2019). *Youth Jobs, Skill and Educational Mismatches in Africa, Working Paper Series N° 326, African Development Bank, Abidjan, Côte d'Ivoire.*

Mthi, S., Yawa, M., Tokozwayo, S., & Ikusika, O. O. (2021). *An Assessment of Youth Involvement in Agricultural Activities in Eastern Cape Province , South Africa*. 1034–1047. https://doi.org/10.4236/as.2021.1210066

Ng'Atigwa, A. A., Hepelwa, A., Manyong, V., & Feleke, S. (2022). Analysis of technical efficiency among youth involved in crop production in Njombe Region, Tanzania. *Cogent Economics and Finance*, *10*(1). https://doi.org/10.1080/23322039.2022.2103923

Nikam, V., Ashok, A., & Pal, S. (2022). Farmers' information needs, access and its impact: Evidence from different cotton producing regions in the Maharashtra state of India. *Agricultural Systems*, *196*(March 2021), 103317. https://doi.org/10.1016/j.agsy.2021.103317

Noltze, M., Schwarze, S., & Qaim, M. (2013). Impacts of natural resource management technologies on agricultural yield and household income: The system of rice intensification in Timor Leste. *Ecological Economics*, *85*, 59–68. https://doi.org/10.1016/j.ecolecon.2012.10.009

Ogunmodede, A. M., Ogunsanwo, M. O., & Manyong, V. (2020). Unlocking the potential of agribusiness in africa through youth participation: An impact evaluation of n-power agro empowerment program in nigeria. *Sustainability (Switzerland)*, *12*(14), 1–18. https://doi.org/10.3390/su12145737

Proctor, F., & Lucchesi, V. (2012). *Small-scale farming and youth in an era of rapid rural change, IIED/HIVOS, London.* https://bit.ly/340il7O

Sakketa, T., & Gerber, N. (2017). Rural Shadow Wages and Youth Agricultural Labor Supply in Ethiopia: Evidence from Farm Panel Data. *SSRN Electronic Journal*, *236*. https://doi.org/10.2139/ssrn.2956283

Selejio, O., Lokina, R. B., & Mduma, J. K. (2018). *Smallholder Agricultural Production Efficiency of Adopters and Nonadopters of Land Conservation Technologies in Tanzania*. https://doi.org/10.1177/1070496518770235

Shayo, A. H. (2020). *The Role Of Education System In Preparing Youth For Agricultural Career Decisions And Aspirations: Exploring Ways To Attract More Youth To Engage In Agriculture And Agricultural Entrepreneurship In Tanzania. Dissertation submitted to the faculty of the Vi*.

Srinivasan, S. (2024). *Becoming A Young Farmer: Young People's Pathways Into Farming: Canada, China, India and Indonesia*. https://doi.org/https://doi.org/10.1007/978-3-031-15233-7_16

Stata Press. (2019). *Stata treatment-effects reference manual: Potential outcomes/counterfactual outcomes release 16*.

Tanzania National Council for Financial Inclusion (TNCFI). (2017). National Financial Education Framework 2016 - 2020 2017 re-print. In *Finance Research Letters* (1st ed., Vol. 8, Issue 2, p. 40). Elsevier Inc. https://doi.org/10.1016/j.jcorpfin.2020.101831

Tarekegn, K., Kamaylo, K., Galtsa, D., Oyka, E., & Panchal, H. (2022). Youth Participation in Agricultural Enterprises as Rural Job Creation Work and Its Determinants in Southern Ethiopia. *Advances in Agriculture*, *2022*, 7–9. https://doi.org/10.1155/2022/5760331

Tumbo S.D., Mahoo, H.F, Mutabazi, K.D., Kahimba, F.C., Kadigi, I. . and M. T. (2017). An Assessment of Tanzania ' s Agricultural Production , Climate Change , Agricultural Trade and Food Security. *The Kenya Institute for Public Policy Research and Analysis (KIPPRA). KIPPRA Working Paper No. 22 2017*.

Uduji, J. I., & Okolo-Obasi, E. N. (2022). Empowerment of rural young people in informal farm entrepreneurship: the role of corporate social responsibility in Nigeria's oil producing communities. *Journal of Enterprising Communities*, *16*(6), 924–947. https://doi.org/10.1108/JEC-04-2021-0054

URT. (2008). *National Employment Policy 2008* (pp. 1–58).

URT. (2016). National Strategy for Youth Involvement in Agriculture. In *Ministry of Agriculture Livestock and Fisheries* (pp. 2016–2021).

URT. (2017). *Agricultural Sector Development Programme Phase II (ASDP II) November, 2017*.

URT. (2021). *"National Five-Year Development Plan 2021/22 - 2025/26: Realising Competitiveness and Industrialisation for Human Development", https://mof.go.tz/docs/news/FYDP%20III%20English.pdf. June 2021*.

URT. (2022). *Building A Better Tomorrow: Youth Initiative For Agribusiness (BBT-YIA) 2022-*

2030 (pp. 1–62).
World Bank (WB). (2011). World development report 2011: Conflict, Security, and Development. *The World Bank, 1818 H Street NW, Washington, DC 20433, USA; Fax: 202-522-2422; e-Mail: Pubrights@worldbank.Org.*
World Population Review. (2022). *World Population Review: Country specific data, https://worldpopulationreview.com/countries/tanzania-population. Accessed 23.04.2022*.
Yeboah, T., Chigumira, E., John, I., Anyidoho, N. A., Manyong, V., Flynn, J., & Sumberg, J. (2020). Hard work and hazard: Young people and agricultural commercialisation in Africa. *Journal of Rural Studies*, *76*(April), 142–151. https://doi.org/10.1016/j.jrurstud.2020.04.027
Zheng, H., & Ma, W. (2020). *Adoption of organic soil amendments and its impact on farm performance : evidence from wheat farmers in China **. 367–390. https://doi.org/10.1111/1467-8489.12406
Zheng, H., & Ma, W. (2023). Smartphone - based information acquisition and wheat farm performance : insights from a doubly robust IPWRA. *Electronic Commerce Research*, *23*(2), 633–658. https://doi.org/10.1007/s10660-021-09481-0

Chapter 4

Agricultural finance

Chapter 4 contains one research paper entitled *"Impact analysis of agricultural finance on crop productivity among smallholder farmers in Tanzania."* The paper has been submitted to a journal for review and publication. This paper investigates the impact of agricultural finance on farm productivity for smallholder farmers. This paper uses cross-sectional data gathered from a farm-based household survey on the project, namely the ''Integrated Project to Increase Agriculture Productivity in the Breadbasket Area of the Southern Highlands of Tanzania," which aimed at promoting food security through agri-food productivity. The impact results from ESR remain valid after a series of tests for endogeneity and selection bias. We compared the ESR results with results from PSM. The results are consistent that beneficiaries augment their crop harvest more than their counterparts. Further analysis suggests that credit-constrained farmers would augment their crop productivity by 15.09% if they were assumed to be credit unconstrained.

Impact analysis of agricultural finance on crop productivity among smallholder farmers in Tanzania.

Abstract

It is evident that developing countries have inadequate agricultural finance, causing considerable credit access constraints for smallholder farm households. The effects of credit access on agricultural productivity in Tanzania remain unclear. It is unclear whether agricultural finance augments agricultural productivity in smallholder farm households. In this context, this study investigates the impact of credit access on productivity in Tanzania, a developing country with weak agricultural finance and significant credit constraints. To achieve the objectives, secondary survey data from a sample of 1042 smallholder farms were used. The ESR model is adopted to address the endogeneity problem and selection bias. The PSM was used to compare the results to ensure the robustness and consistency of the results. In both models, the results are consistent, and credit access positively affects smallholder farm productivity. Interestingly, farmers without credit counterfactuals would increase their productivity by 15.09% if there were no credit constraints. The findings have important policy implications in favour of smallholders' access to credit, which will impact food security and poverty reduction through crop productivity augmentation, in light of the Sustainable Development Goals (SDGs) attainment.

Key Words: Tanzania, agricultural finance, credit constraints, agricultural productivity, ESR, PSM, smallholder farmers, impact analysis.

1. Introduction

Agricultural finance is weak in most African countries, amplifying agricultural credit constraints on farmers. The smallholder farm households are even greatly constrained (Acclassato et al., 2021). There are approximately 570 million smallholder farms worldwide that cultivate less than 4.9 acres or 2 hectares[2] (Roop et al., 2023). Small farmers increasingly occupy a large share of the farming population and produce 69% of food (FAO, 2015).

Agricultural finance is crucial for agricultural growth, which contributes to the attainment of some Sustainable Development Goals (SDGs), such as ending poverty and hunger, job creation, and economic growth (Christiaensen & Martin, 2018; UN, 2015). The African economy's overdependence on the agricultural sector increases the necessity of credit support to boost the crop productivity of smallholder farmers (Assouto et al., 2023).

Agriculture in Tanzania is largely informal, employing 80% of the rural poor population, who survive due to agricultural activities (URT, 2016). The sector employs 75% of the total labour force, food and cash crops account for 70% of rural incomes, 65% of raw materials to processing industries, contributes 29% of GDP, and 30% of export earnings (URT, 2017), and the emerging manufacturing factories depend on agriculture for raw materials in Tanzania (Ogada et al., 2021).

[2] One acre is estimated to be 0.4 ha (Nikam et al., 2022).

In the Tanzanian context, household farm households may mean that household farmers who cultivate small plots mainly inherited from elders and have a permanent labor force. Given the size of the farms, they can employ external laborers (FAO, 2015). The resources used for farming belong to the household head. The farms are mainly used to cultivate food, cash, or both crops (FAO, 2018), and the household head may decide to consume or sell the surplus.

The size of farm/plot of a cultivated area poses disagreements in many areas (FAO, 2015), but in Tanzania, small farms are 0.9 hectares (2.22 acres) (FAO, 2015; TNCFI, 2017). The disagreement on the farm size, normally the suggestion of the national or regional is considered (Acclassato et al., 2021). A farm size of 2.22 acres or less will be considered as small farm threshold for this study (FAO, 2015). However, medium-sized farms are 5.44 acres and large-sized farms are 10.13 acres in Tanzania (FAO, 2015; TNCFI, 2017). In fact, most societies in Africa, Asia, and Latin America that deal with agriculture fall under smallholder farmers (FAO, 2015), and this study focuses merely on smallholder farmers who hold a large segment of the farming population in Tanzania as the main producers of food crops

Financing agricultural productivity in Africa is debatable because of the existence of large- and small-scale farming systems with different characteristics. The existence of pro-large and pro-small farmers affects their coexistence as they affect their credit access (Acclassato et al., 2021). The context makes smallholder farmers credit access constrained, and they fail to meet global challenges (FAO, 2010). Pro-large farmers believe that international entities in developing nations will improve agricultural production through agricultural financing programs (Gikonyo et al., 2022).

These practices drive smallholder farmers out of the agricultural market (Cotula et al., 2009). The interconnection of agricultural systems to meet people’s demand requires high quality agricultural products, which incurs high farming costs that small household farmers cannot afford (Mohammed Seidu & Tanko, 2022).

Importation as a policy option of many African government facing food insecurity rather than boosting crops production. They lower crop prices, create jobs and income of smallholder farm households. Importation harms the domestic economy, and small farmers fail to be competitive given the economy of scale of importers. Small farmers are locked into low-standard crop products that are unable to compete with others because competition is very expensive for them and they are unable to generate significant profits for credit repayment (Ogada et al., 2021).

Small-scale farmers face climate change impacts and hazards, limited access to capital and financial services, and inadequate credit support (URT, 2016b; Maiga, 2016; Winthrop et al., 2018). Only large farmers can withstand challenges because they have resources or can access credit, unlike small-scale farms, which are considered risky (Acclassato et al., 2021; Gikonyo et al., 2022). The pro-large-scale and agribusiness companies claim that smallholder farm households are unviable, that financial institutions cannot deal with them, and that most of them are scattered in the informal sector (Tripathi, 2017).

The existence of negative perceptions and challenges about financing agriculture, especially small-scale farmers, prevents them from certainly accessing agricultural credit. Subsequently, low agricultural productivity, failure to compete in both local and international markets, and food insecurity have been predominant. Some who get credit fail to generate margins for interest rate repayment that jeopardize future credit applications due to unreliable prices (Acclassato et al., 2021). Low income and persistence of poverty that fuel poor standards of living among many farmers (Osabohien et al., 2020)

The pro-smallholder farm households argue that private and public credit access facilitation to all farmers is crucial. Financial support to smallholder farm households enables them to improve crop productivity from their small plots. For instance, Tanzanian small farmers with a cultivated area of 2.22 acres can generate on average about 780 USD against 280 USD from a larger farm of 10.13 acres (FAO, 2015).

Furthermore, the extant literature presents controversial findings about the nexus that exists between farm size and crop productivity (Mishra et al., 2023). Some studies argue that smaller farms are more productive per unit of land, and others elucidate that larger farms are more productive overall (Rada & Fuglie, 2019). However, in terms of resource ownership, large farms, while fewer in number, often exhibit higher productivity and efficiency through greater mechanization and adoption of advanced technologies, unlike the smallholder farmers who are financially constrained (Jelsma et al., 2019). Smallholder farmers, especially in SSA, are characterized by scarce resources in terms of technology and the capital to invest in farming (Acclassato et al., 2021; Assouto et al., 2023).

Small farmers are potential for agricultural productivity and income if they can have reliable access to financial services and products for their agricultural operations (Rashid, 2021). Pro-smallholder farming believes that agricultural development without credit support to small-scale farming is difficult to end poverty (Balana et al., 2022). Smallholder farm households are likely to keep using rudimental farming tools if the financial markets will not function in their favour (Girma, 2022).

Financial access can improve small farmers' risk diversification and increase investment in agriculture (Tripathi, 2017; Gikonyo et al., 2022). Eventually, augment productivity and raise the income of millions of smallholder farmers, improve food security, and improve the standard of living (Salima et al., 2023). Supporters of small-scale farming claim that without agricultural credit, it is difficult for smallholder farm households to conduct agriculture by turning it profitable (Osabohien et al., 2020).

Inadequate credit support to small-scale farmers is linked to the difficulty of agricultural inputs uptake, such as improved seed, organic and inorganic fertilizers, and herbicides (Rashid, 2021). It is obvious that farmers' access to credit not only improves agri-production, food security, income, standard of living, and poverty reduction (Agbodji & Johnson, 2019; Chandio et al., 2021; Nakano & Magezi, 2020; Rashid, 2021; Salima et al., 2023), but also enhances smallholder farm households shift from merely a substance to market-oriented agriculture (Acclassato et al., 2021). Credit access improves resilience to climate-induced shocks and the ability to manage risks in agriculture (Winthrop et al., 2018).

Credit rationing theory by Stiglitz & Weiss (1981) in financial institutions is prevalent in Tanzania, coupled with transaction costs, leading to credit market failure (Converse et al., 2012; Bonnke et al., 2022). Some are unable to access credit due to a lack of bankable collateral (URT, 2016), high interest rates (Winthrop et al., 2018), and risk perceptions about credit (Balana et al., 2022). Even the microfinances that operate at the grassroots level where farmers are found are not fully financing smallholders farmers (Nakano & Magezi, 2020; Rashid, 2021). Commercial banks devote a small share of grants to agriculture, mainly financing agro-processing activities.

Similarly the government of Tanzania, through the Tanzania Agricultural Development Bank (TADB), does not sufficiently meet the credit demands in the agriculture sector through its Smallholder Credit Guarantee Scheme (SCGS) Performance, which concentrates on agro-processing and factories (TADB, 2020). At the same time, Tanzanian agricultural policies are implemented at the sectoral level, leaving a gap between the farmers and the policies. For instance, a collective action under Kilimo Kwanza *"Agriculture First"* has not achieved the expected outcome because it is not well coordinated and the resources are insufficient to reach all small-scale farmers (Yami et al., 2019).

The challenge affects the achievement of the Tanzanian Development Vision by 2025 of being middle income country and the Sustainable Development Goals (SDGs) of ending poverty and hunger in the country. Lack of access to credit by smallholder farmer limits adoption of innovation and cost-effective technologies (Nakano & Magezi, 2020; Balana et al., 2022).

The results in the current study confirm that smallholder farm households' credit access augments agricultural productivity in Tanzania. Studies on credit access in Tanzania exist, but their findings are conflicting (Nakano & Magezi, 2020; Rashid, 2021) and rarely focus on impact evaluation of credit access by smallholder farm households. In the Tanzanian context, it is still questionable if credit access by small-scale farmers augments their agricultural productivity. The gap in literature justifies this investigation and the following questions guided the investigation: Why are farmers refused agricultural credit? Why do some farmers not apply for credit? What determines credit access by smallholders? What is the impact of credit access on agricultural productivity?

The rest of the paper is structured as follows: Section 2 summarizes the literature review, section 3 shows the methodology, section 4 presents results and discussion, and section 5 contains discussion and policy implications of the findings.

2. Literature Review

The literature reflecting the impact of credit access on agricultural productivity claims a causal relationship. Small-scale farmers with credit access possess important agricultural inputs in comparison with farmers without credit access (Ali et al., 2014; Assouto et al., 2023; Bonnke et al., 2022; Chandio et al., 2021; Hu et al., 2019; Y. Hu et al., 2021; Osabohien et al., 2020; Rashid, 2021; Salima et al., 2023).

The extant literature presents several empirical studies reflecting the impact of agricultural finance, farms, and socio-economic profiles on agricultural productivity. Acclassato et al. (2021) studied agricultural finance and crop productivity in Benin using Endogenous Switching Regression (ESR) and Propensity Score Matching (PSM) models. The study concluded that finance is positively related to agricultural productivity. Further, a study highlighted that improvement in the productivity of farmers with access to credit was evident due to increased use of inputs such as fertilizers, improved seeds, hiring labour, and technologies that set the optimal production conditions per hectare in Benin (Assouto et al., 2023).

Further, credit access in Nigeria has a long impact on agricultural productivity, which calls for sustainable credit support to small-scale farmers (Osabohien et al., 2020). The same situation in Ghana is that microcredit programs for small farmers increase productivity and improve the income of the small-scale farmers (Missiame et al., 2021).

Using ESR and PSM models in Togo, access to credit increased cereal productivity (Agbodji & Johnson, 2019), whereas Nakano & Magezi (2020) obtained conflicting results on the impact of microcredit on agricultural technology adoption and productivity in Tanzania. Farmers with microcredit used more chemical fertilizer than their counterparts. Microcredit doesn’t augment yield, profit, and income per hectare more than those who had better access to irrigation facilities. Implying that access to credit alone does not augment farm performance, other inputs are crucial.

Further, Mukasa et al. (2017) in Ethiopia identified the constraints that small-scale farmers face in the financial market that hinder them from accessing credit for agriculture and affect productivity. The findings are in line with the studies in the literature, such as those of Balana et al. (2022) in Tanzania and Ethiopia. This paper has examined constraints that hinder farmers from accessing agricultural credit in furtherance of credit access's impact on crop productivity.

Chandio et al. (2021) studied the impact of formal credit on agricultural production in Pakistan. The findings affirm the positive significant impact of formal credit on agricultural productivity and the overall income of the farmers.

Tripathi (2017), using descriptive and literature review, analyzed the impact of credit on agricultural productivity in India. The study reveals that credit constraints have an impact on agricultural productivity and income. Credit access improves inputs uptake, such as improved seeds and fertilizers, which are crucial in crop productivity and income augmentation.

Studies on the impact of credit on agricultural productivity in Peruvian agriculture show a positive and statistically significant impact (Guirkinger & Boucher, 2008), and in China, credit access improved grain productivity and wholesale supply of grains (Hu et al., 2019).

Using panel micro data with a globe perspective such as from Africa (Malawi, Tanzania, and Uganda), Asia (Bangladesh), Southern America (Brazil), Northern America (United States), and from the Pacific (Australia) highlights that farm size and productivity show advantages to smaller or large sized farms. The findings in these places suggest that large farms have access to resources such as finance, but they relatively use high labour costs that reduce their gains. Small holder farmers are constrained in them of resources such as finance but they are relatively use labour (family) intensive which serve as a relative advantage to reduce costs per unit land which eventually boost their gains in crop farming (Rada & Fuglie, 2019).

Further, information source channels such as radio and television (TV) are predominantly used by farmers to access information related to agricultural practices (Blazquez-Soriano & Ramos-Sandoval, 2022). Recent empirical studies confirm that radio and TV have a positive impact on the usage of inputs, changing agricultural inputs that augment crop yields and income in India (Nikam et al., 2022; Vasudevan, 2023). In Kenya radio and TV edutainment programs improve productivity and income (Areal et al., 2020). Radio and TV are factors that influence productivity in this paper.

Synthesis of empirical literature shows that agricultural finance is positively related to agricultural productivity but is amplified by the presence of covariates in the ESR and PSM models. It appears that variables influencing productivity may depend on credit access, farm, social, economic, and demographic characteristics of the smallholder farm households.

3. Methodology

3.1. Data Sources

This paper used secondary data. The data are cross-sectional, gathered from a farm-based household survey in the project namely ‘‘Integrated Project to Increase Agriculture Productivity in the Breadbasket Area of Southern Highlands of Tanzania,” which aimed at promoting food security through agri-food productivity.

The survey covered two regions, Songwe and Mbeya. The sample size involved 1443 smallholder farm households. Multistage sampling was opted to get the respondents. The purposive sampling was applied to select the regions (Songwe and Mbeya). In the Songwe region, two districts (Mbozi and Momba) were selected, and in the Mbeya region, two districts (Mbarali and Mbeya Rural) were involved in the survey.

The selection criteria of regions and districts are based on their potentialities in agri-food production of staple foods (rice, maize, and beans) in Tanzania and assurance of food availability. Furthermore, the survey used proportional random sampling to select 51 out of 92 wards in the sampled districts. Farmers’ Organizations (FOs) registered in each ward were identified. A systematic random sampling technique was applied to get a sample size of 1443 households as members in the FOs. Data was collected by visiting a household. Before questioning them, a written consent was read to them to agree and sign that they are willing to respond to the interviewer.

Then data was collected using structured questionnaires. Detailed information was collected, such as demographics, socio-economic profiles, Climate Smart Agriculture (CSA) technologies, crop production, food consumption, agricultural finance, farm, and farmer-specific characteristics. The survey was carried out in collaboration between Wageningen University in

Germany, Research Centre (WUR), and Sokoine University of Agriculture (SUA) in Tanzania. After cleaning the data and dropping the missing data, the data remained with a clean data set of 1042 farmers.

3.2. Variables

Variables used in the econometric analysis were selected based on theories and empirical literature. In line with the previous studies (Mukasa et al., 2017; Agbodji & Johnson, 2019; Assouto et al., 2023; Chandio et al., 2021; Guirkinger & Boucher, 2008; Hu et al., 2019; Missiame et al., 2021; Mohammed Seidu & Tanko, 2022; Osabohien et al., 2020; Salima et al., 2023).

Credit access status is treated as a dummy variable where 1is for accessed credit and 0 if otherwise. It is the choice/selection model we used in the model specification and is consistent with other studies in the previous literature (Assouto et al., 2023; Guirkinger & Boucher, 2008; Rashid, 2021).

A summary of statistics and an explanation of various variables are depicted in Table 1. Variables are statistically significantly or insignificantly different between the beneficiary and non-beneficiary farmers. The variations between the two groups may imply that they are systematically different; hence, there is a potential selection bias. The adoption of the ESR model is appropriate to address the potential selection bias. However, the variations in findings in the literature may mean flaws in data or functional model misspecification and variables included in the models (Sakketa & Gerber, 2017).

Further, the study considers agricultural productivity as a continuous dependent variable that is influenced by credit access in affiliation with other covariates. Agricultural product is the total output (yields) per hectare in kilograms (Akter et al., 2022). In this paper, agricultural productivity is measured by aggregating the total harvest in kilograms per acre divided by the size of the cultivated area in acres, just like in Ethiopia (Mukasa et al., 2017) and Benin (Assouto et al., 2023) when investigating the effect of credit access on crop-specific productivity.

Table 1. Statistics and description of key variables used in the model analysis

Variables	Description	Reference	With	Without	Difference

Dependent Variable					
Outcome variable (*Lnprdtyttalmrbkg*)	Total harvest in Kilogram (Kg) per acre divided by the size of cultivated area.	Seidu &Tanko, 2022	3308.96	3265.27	44.69*** (40)
Agri. Inputs					
Cultivate area (*total_acres*)	The size of the farm/plot cultivated (in acre)	(Mukasa et al., 2017)	-0.595 (0.058)***	-0.478 (0.065)***	-0.117*** (0.062)
Improved seed (*ImpvdSeds*)	If the farmer uses improved seeds	(Acclassato et al., 2021)	0.502 (0.142)***	0.376 (0.117)***	0.126*** (0.129)
Inorganic fertilizers (*UsdChmcFert*)	If the farmer uses manufactured fertilizers	(Mukasa et al., 2017)	0.709 (0.194)***	0.522 (0.223)***	0.187*** (0.209)
Organic manure (*UsdOgncFert*)	If the farmer uses organic manure	(Mukasa et al., 2017)	0.363 (0.149)**	0.146 (0.137)	0.217 (0.143)
Used Herbicides (*UsdHerbcides*)	If the farmer uses herbicides	(Mukasa et al., 2017)	0.435 (0.113)***	0.057 (0.111)	0.378 (0.112)
Practiced Irrigation (*PrctIrgation*)	If the farmer practices irrigation	(Mukasa et al., 2017)	3.062 (0.508)***	3.522 (0.425)***	-0.46*** (0.467)
Access					
Training rate (*ExtnSevcVst*)	Number of visits a farmer received from extension services	(Salima et al., 2023)	0.495	0.456	0.040
Infrastructure (*AccssdRoad*)	If improved roads are available	(Ali et al., 2014)	0.001 (0.681)	0.000 (0.535)	0.001 (0.608)
Distance to farm (*DstncToFrm*)	The distance from dwelling place to the farm expressed in km	(Missiame et al., 2021)	2.738 (1.738)	2.765 (1.871)	-.027 (0.212)
Wealth					
Value of Assets (*Total_asset*)	The value of assets owned by the farmer	(Nakano & Magezi, 2020)	0.07*** (0.026)	0.00(0.003)	0.07*** (0.015)
Socioeconomics					
Age (*HhAge*)	Age of a farmer in years	(Ali et al., 2014)	–0.002 (–0.905)	0.001 (0.510)	-0.003 (-0.198)
Sex (*HhGender*)	Being a male or female	(Assouto et al., 2023)	0.275 (0.277)	−0.195 (0.121)	0.47 (0.199)
Education (*HhEdctn*)	Level of education	(Ali et al., 2014)	0.023 (1.645)	–0.001 (–0.097)	0.024 (0.774)
Marital Status (*HhMrtalSt*)	Whether the farmer is married or not.	(Salima et al., 2023)	0.761	0.698	0.063**
Household size (*Lnhhsize*)	Number of household's members	(Guirkinger & Boucher, 2008)	56.55** (20.31)	38.94 (21.02)	17.61 (20.67)
Experiences (*Lnfarmexper*)	Years the farmer had spent dealing with agriculture.	(Assouto et al., 2023)	−0.010 (0.131)	0.036 (0.037)	-0.046 (0.084)
Using source of agr. information					
Owning and using (*HhOwnRadio*)	If the farmer owns Radio and uses it to get agricultural information	(Vasudevan, 2023)	0.150** (0.073)	0.019 (0.048)	0.131 (0.0605)
Owning and using (*HhOwnTV*)	If the farmer owns TV and uses it to get agricultural information	(Armel Nonvide, 2023)	10.97 (0.0043)	10.33 (0.0047)	0.64*** (0.0064

Note: *, **, *** indicate significance at the 10%, 5%, and 1%, levels, respectively

Source: Field Survey (2018).

3.3. Theories and the conceptual framework underpinning the study

The theories that underpin this study are utility, production and credit rationing. Famous economic theory "Utility theory" reflects individuals' preferences. The theory is assumed to explain the producers' or consumers' behaviour (Akter et al., 2022). The theory argue that choice is reached based on maximum satisfactions attained (Fishburn, 1970).

A rational small farmer's satisfaction refers to the benefits/profits/utility derived. In this context, smallholder farm household's choice to apply for credit is binary. He/she may decide whether to apply for credit or not and the decision is based on the satisfaction maximization for the decision made and the impact of credit access on productivity and standard of living. Benefits/profits of farmers with credit Y_{1i} in comparison with farmers without credit Y_{0i}. Farmer i^{th} can opt to go for credit if $Y_{1i} > Y_{0i}$ and the net benefits is U_{1i}>0. Despite the farmer's preference and credit access status are clear to farmer and researcher, the net benefit is unobservable.

Thus, $U_{1i}^{*} = Y_{1i} - Y_{0i} > 0$ ………………………………………………………… (i)

Farmers apply for credit may get full or be declined at all due asymmetric information that leads to credit market failure (Bonnke et al., 2022; Stiglitz & Weiss, 1981). Financial institutions and other money lenders adopt credit rationing given the existence of asymmetric information in the financial market (Stiglitz & Weiss, 1981). In reflection of credit rationing theory, we get credit unconstrained and constrained farmers (Acclassato et al., 2021).

The production theory relates agricultural output (crop harvest per acre) given agricultural inputs and other factors (such as credit) at a particular level of technology (Forsund et al., 1980; Missiame et al., 2021). The theory shows the technical link between agricultural inputs and crop productivity and demonstrates the optimal productivity given the fixed inputs (Lovell, 1993; Farrell, 1957) so that variables that influence the productivity can be realized (Meeusen & van Den Broeck, 1977). Under the production theory, the study adopted the Cobb-Douglas production function, which can be expressed as:

$Y_{1i} = AL^{\alpha 1i} K^{\alpha 2i} Q^{\alpha 3i}$ ………………………………………………………… (ii)

Where; Y_{1i} is productivity per acre, A is a constant term, L is labour employed (hereof household members), K is capital (hereof fertilizers, plot size), Q represents other factors used in production (hereof socio-economics) while $\alpha 1i$, $\alpha 2i$ and $\alpha 3i$ are estimated vector elasticities.

Theories in agriculture at the household level and literature reviews on credit access (Girma, 2022; Missiame et al., 2021; Seidu & Tanko, 2022) posit that credit access by smallholder farm households enhances adoption of new innovation and technology and improves crop productivity. With credit access, crop productivity is augmented and management of crops in plots is improved. Farmers can delegate and have time to engage in other off-farm jobs (Rasheed et al., 2020).

Therefore, the impact of credit access on the outcome variable (crop productivity) follows that the net benefit from credit access in eqn. (i) is determined by observable variables (hereof farm, farmer, and socioeconomics) and the unobservable factors such as motivations affecting farmer decisions $£_i$ such that,

$$U_i^* = \beta X_i + \gamma G_i + \varepsilon_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . (iii)$$

Where: U_i^* is the productivity of i^{th} smallholder farm household, Xi is a vector of farm and socio-economic profiles (hereof gender, age, education, plot size), G_i is credit access status of each i^{th} farm household, β and γ are coefficients to be estimated, and ε_i is the error term with zero mean and constant variance δ^2

The synthesis from both theoretical and empirical literature reviews enables us to compose the conceptual framework. Figure 1 shows the reasons why there are credit refusals and some fail to apply for credit. The Figure. depicts the positive causality between credit access and agricultural productivity given the improved input uptakes, application of improved tools, and involvement in financial markets. According to the conceptual framework in Fig.1, two important hypotheses are tested.

H1: Credit access augments agricultural productivity.
H2: Farm characteristics and socioeconomic status affect credit access and productivity.

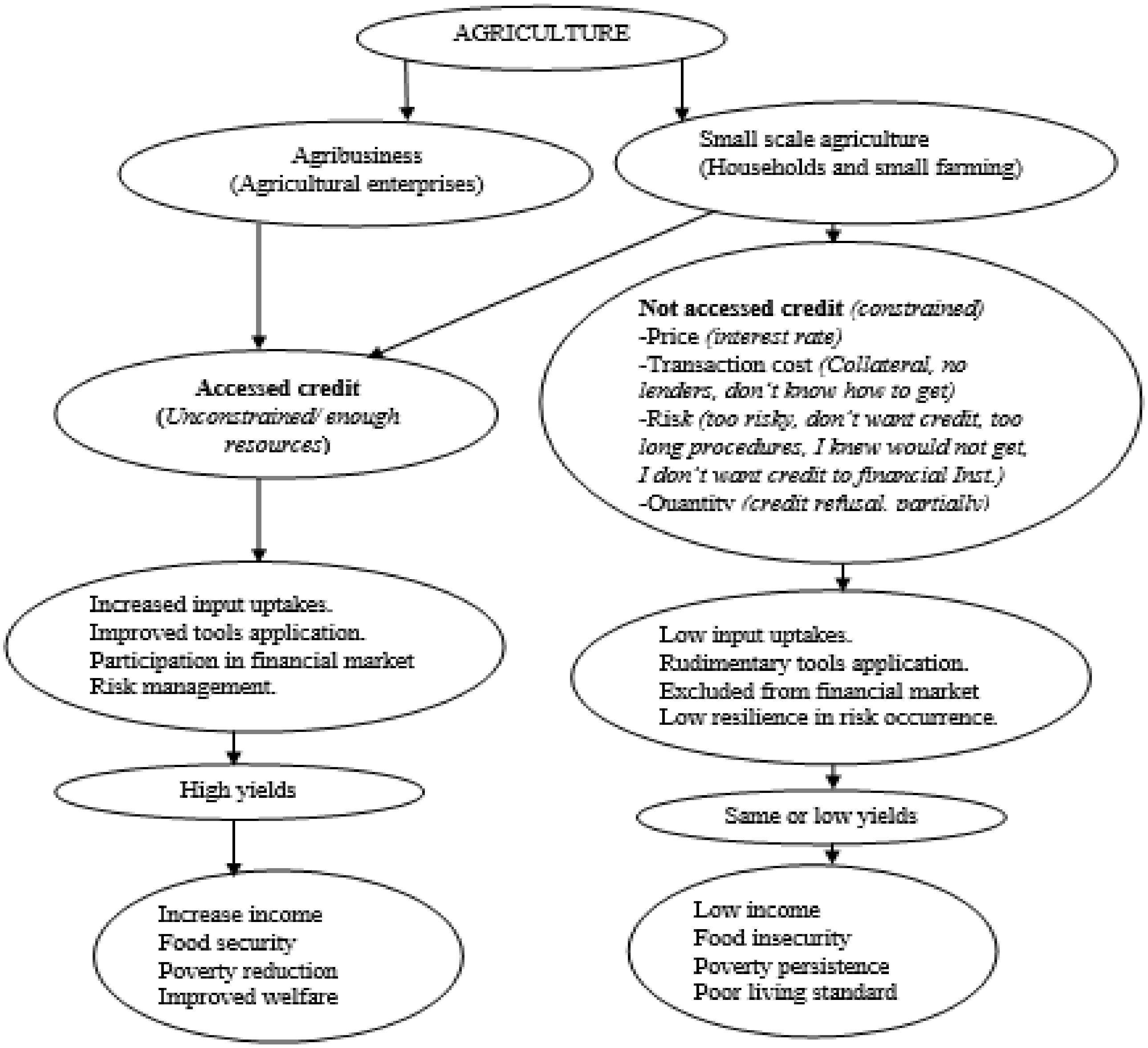

Figure 1. The conceptual framework
Source: Author 2023

3.4. Econometric strategies

The theoretical and empirical literature review reveals that there are several frequently used techniques in the estimations of the causal effects of agricultural finance on agricultural productivity. Commonly used econometric techniques include the Linear Probability Model (PSM, probit, and bivariate probit models, and Heckman selection) and the linear regression model with endogenous treatment effect (ESR) (Acclassato et al., 2021; Qin et al., 2022; Ho et al., 2021).

This paper adopts the ESR model and PSM for comparison of the consistency of the results. The ESR has the power to address various biases in the impact evaluation assessment. For instance, the prevalence of endogeneity and sample selection can be addressed by the ESR model. During analysis using Stata Ver 18, we specified robust standard error (S.E.) to address the potential heterogeneity between the two groups of farmers (Guirkinger & Boucher, 2008; Ali et al., 2014; Mukasa et al., 2017; Assouto et al., 2023).

The specification of the ESR model is presented in two steps in this study. The first step is the probit model, which estimates the determinants of credit access, and the second consideration is the outcome variable that is divided into two dependents of unconstrained and constrained farmers.

Recall eqn. (i):

Assume that the difference in benefits between beneficiary and non-beneficiary farmers is unobservable. The farmer's preferences can be represented as a "*latent variable*" for credit access.

Thus, $Credit\ Access_i^*(Y_i) = \gamma_i \mathrm{A}_i + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (iv)$

$$Y_i = \begin{cases} 1 \text{ if a farmer got credit} \\ 0 \text{ if a farmer did not get credit} \end{cases}$$

Where: A_i vector of farmer' i^{th} attributes that enable to access credit, γ_i vector of coefficients, ε_i is error term

Step two of the ESR model is the estimation of the causal effect (impact) of accessing credit on agricultural productivity. Consider the following specifications.

From eqn. (ii) and (iii). It follows that;

$y_i = \beta Z_i + \gamma WithCredit_i^* + \mu_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (v)$

Where;

y_i Farmer i^{th} productivity, Z_i farmer's i^{th} characteristics, β & γ are coefficients, and μ_i random error term.

Refers to eq. (v), the productivities observed for the two groups (beneficiary and non-beneficiary farmers) (Maddala, 1986), as it has been used in several impact studies (Mukasa et al., 2017; Agbodji & Johnson, 2019; Ali et al., 2014; Assouto et al., 2023; Chandio et al., 2021; Guirkinger & Boucher, 2008; Missiame et al., 2021; Salima et al., 2023), then it follows that:

$$Regime1: Y_{1_i} = \partial_1 A_{1_i} + \varepsilon_{1_i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (vi)$$

$$Regime2: Y_{2_i} = \partial_2 A_{2_i} + \varepsilon_{2_i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (vii)$$

Where; Y_{1_i} & Y_{2_i} beneficiary (treated) and non-beneficiary (untreated) farmers respectively, A_{1_i} & A_{2_i} exogenous covariates, ∂_1& ∂_2 coefficients, ε_{1_i} & ε_{2_i} error terms.

Consider the error terms for eq. (iii), (vi), and (vii) may be jointly normally distributed, and some unobserved factors that affect the probability of credit access (being constrained/unconstrained) are likely to influence the outcome variable (crop productivity) (Ali et al., 2014). In this context, the error terms for credit access (selection/choice model) and the outcome (crop productivity) equations are assumed to be correlated. Without resolving this problem, the results from OLS are potentially biased (Mukasa et al., 2017). Addressing this problem of endogenous switching, we estimate the parameters of both equations simultaneously using the *Full Information Maximum Likelihood (FIML),* which is the most efficient technique to estimate impact evaluation models with endogenous switching (Acclassato et al., 2021), assuming there are no specification errors. In this situation consistent standard errors are generated (Lokshin & Sajaia, 2004). It is possible to compare the crop productivity of the individuals who can access credit (treated) and the individuals who were unable to access credit (untreated). It further estimates the crop productivity of their respective counterfactuals.

The effects of a farmer's access to credit on crop productivity are obtained through the next eq. (viii), which can be called "Treatment Effect on Treaties" (TET) (Heckman, 2001), as follows:

$$TET = E(y_{1_i}/WithCredit_i = 1) - E(y_{2_i}/WithCredit_i = 1) \ldots\ldots\ldots\ldots\ldots (viii)$$

For the "Treatment Effect on the Untreated" (TEU), it will be obtained as follows:

$$TEU = E(y_{1_i}/WithCredit_i = 0) - E(y_{2_i}/WithCredit_i = 0) \dots \dots \dots \dots \dots \dots \dots (ix)$$

Apart from the contribution of credit access to agricultural productivity, covariates ranging from agricultural inputs, farms, information sources, and socio-economic profiles are presented in the ESR model. The study employed elasticity techniques to examine the contributions of these variables to crop productivity as follows:

$$\frac{\Delta Agri.prdctvt \quad (\Delta Ag.Prdt)}{\frac{Agri.prdctvt \ (Ag.Prdt)}{\frac{\Delta X_i}{X_i}}} = \frac{\Delta Ag.Prdt}{Ag.Prdt} \ x \frac{X_i}{\Delta X_i} = = \frac{\Delta Ag.Prdt}{\Delta Xi} \ x \ \frac{Xi}{Ag.Prdt} \dots \dots \dots (X)$$

Thus, productivity $(Ag.Prdt)$ = $e^{\sum_1^n \beta_i X_i} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (xi)$

Further, eqn. (x) it can be written as

$$\frac{\Delta Ag.Prdt}{\Delta Xi} = \beta_i Ag.Prdt \quad \text{and} \ \frac{\Delta Ag.Prdt}{\frac{Ag.Prdt}{\frac{\Delta Xi}{Xi}}} = \beta_i Ag.Prdt \ x \ \frac{X_i}{Ag.Prdt} \dots \dots \dots \dots \dots \dots \dots \dots (xii)$$

Then the elasticity is presented as:

$$\frac{\Delta Ag.Prdt}{\frac{Ag.Prdt}{\frac{\Delta X_i}{X_i}}} = \beta_i X_i \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (xiii)$$

Therefore, the interpretation is done by multiplying 100 as follows:

$$100 \ x \ \beta_i = \frac{100x \frac{\Delta Ag.Prdt}{Ag.Prdt}}{\Delta X_i} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (xiv)$$

Finally: $(100 \ x \ \beta_i)\Delta X_i = \ \%\Delta Ag.Prdt \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (xv)$

The results are interpreted that, a 1% increase in X_i cause crop productivity to increase by $100 \ x \ \beta_i$ holding others equal for continuous variables (X_i), given the coefficients are in semi-elasticity.

In our model the dummy variables are interpreted differently from continuous variables such that $[\text{exponential}\ (\beta i) - 1]\ \%$ is the average differential crop productivity between the reference and the expressed categories.

After getting the estimates of the productivities of farmers, a mathematical formula was used to punctuate the difference between the predicted crop productivity of beneficiary and non-beneficiary farmers. Therefore,

$$\text{Gain} = \frac{E\left(\frac{(\widehat{Ag.Prdt_1}}{WithCredit = 1}\right) - E\ (\widehat{Ag.Prdt_0}/WithCredit = 1)}{E\ (\widehat{Ag.Prdvt_1}/WuthCredit = 1)} \ldots\ldots\ldots\ldots\ldots (xvi)$$

The higher the value, the greater the agricultural productivity gains due to credit access and the greater the necessity to work with financial markets, minimizing credit constraints for farmers.

4. Results and discussions

4.1. Descriptive analysis

The conceptual framework reveals the reasons as to why some farmers are constrained, some are not, and other farmers do not apply for agricultural credit. Figure 2 contains reasons for credit refusal and reasons why some farmers never apply for credit.

About 61.76% of respondents reported that their applications were declined because they presented no collateral, and 14.71% said they were declined because they lacked some important documents. Mukasa et al. (2017) found the same situation in Ethiopia: that smallholder farmers failed to access credit. Developing countries that share some economic characteristics, especially in the SSA.

On the other hand, those who never attempted a credit application said it was too risky to take credit (22.51%), meaning the interest is too high and the possibility of paying it back is uncertain which may lead to selling their assets they placed as collateral. Surprisingly, about 19.44% of farmers don't know the procedures to apply for credit from financial institutions. About 13.81%

of farmers who never applied for credit said financial institutions charge high interest rates, and about 2.81% said there are no financial institutions near them.

At the same time, about 20.84% of farmers who did not apply for loans said they don't prefer to take loans. May imply they have enough resources or support for their farming. Some studies are in line with these findings, that lack of bankable collateral is one of the major barriers for smallholders to access credit in Ethiopia and Tanzania (Balana et al., 2022; Xiao et al., 2021; Xiong et al., 2023). It is crucial for the Tanzanian government to regulate land tenure to make land bankable collateral. Also, lenders strategically offer collateral-free credit to enable many smallholders to access credit to be able to improve their farm performance.

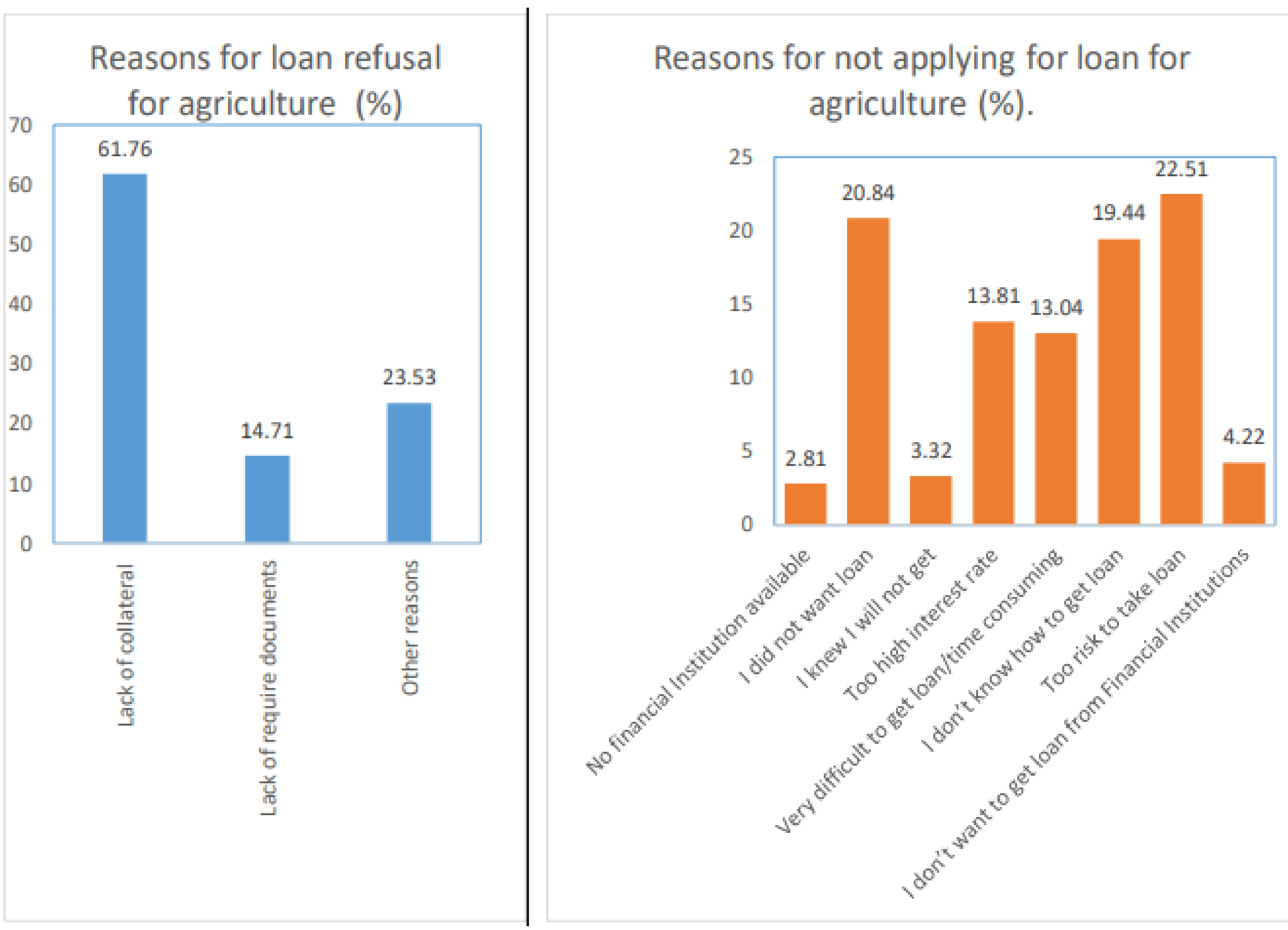

Figure 2. Reasons for loan refusal and not applying for loan for agriculture
Source: Field Survey (2018).

Table 2 summarizes the variables used in econometric analysis. The variables include credit access (*CrdtAccess)* as the choice variable and the outcome (crop productivity). Further, Table 2 contains the covariates such as cultivated area *(total_acres)*, assets *(total_asset)*, improved seeds *(ImpvdSeds)*, inorganic fertilizers *(UsdChmcFert)*, organic fertilizers *(UsdOgncFert)*, herbicides *(UsdHerbcides)*, irrigation *(PrctIrgation)*, farmer's experience *(farmexper)*, rate of training *(ExtnSevcVst)*, access to the market *(AccssdRoad*), distance to the farm *(DstncToFrm)*, using radio *(HhOwnRadio)*, using TV *(HhOwnTV)*, being a man *(HhGender)*, years spent on education *(HhEdctn)*, and household size *(hhsize)*.

Farmers on average cultivated 5.768 acres (2.334 hectares). These farmers cultivate a minimum of 7.688 acres (3.111 hectares) and a maximum area of 90 acres (36.423 hectares). Statistics show that farmers vary in terms of experience. Some farmers have spent about 66 years, and some are beginners with a minimum of only 1 year in the field. Some use experience to manage risks in agriculture that improve their farming techniques and productivity. Family farmers look like they are locked with no access to the market.

They spend on average 58.064 kilometers reaching the market to sell their crops. Many have farms/plots located far from their dwelling places, about18.263 kilometers on average. Furthermore, farmers prefer using improved seeds as advised by extension services officers. About 56.2% used improved seeds, the rest preferred local seeds. Due to their link to farm performance improvement, 83.3% of farmers prefer using inorganic fertilizers, while 34.9% prefer organic fertilizers. Further, the analysis highlights that about 59.2% of the respondents used herbicides, and only 23.9% of farmers irrigated their farms/plots.

Table 2. Descriptive statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
prdtyttalmrbkg	1042	1763.346	6380.144	15	204222
CrdtAccess	1042	.25	.433	0	1
Total_acres	1042	5.768	7.688	0	90
Total_asset	1042	1418305.1	3989011.5	0	55910000
ImpvdSeds	1042	.562	.496	0	1
UsdChmcFert	1042	.833	.373	0	1
UsdOgncFert	1042	.347	.476	0	1
UsdHerbcides	1042	.592	.492	0	1
PrctIrgation	1042	.239	.427	0	1
farmexper	1042	22.319	13.818	1	66

ExtnSevcVst	1042	.148	.355	0	1
AccssdRoad	1042	58.064	59.898	0	300
DstncToFrm	1042	18.263	16.526	0	142
HhOwnRadio	1042	.64	.48	0	1
HhOwnTV	1042	.243	.429	0	1
HhAge	1042	50.67	13.382	21	102
HhGender	1042	.839	.368	0	1
HhEdctn	1042	6.036	2.81	0	11
HhMrtalSt	1042	.805	.396	0	1
hhsize	1042	5.327	2.229	1	16

Source: Field Survey (2018).

Table 3 summarizes the partial correlation between the dependent variable productivity (*Lnprdtyttalmrbkg*) and the covariates involved in the model. Irrigation augments crop productivity. Also, years spent on education are positively related to improvement in productivity. The contribution of these factors might imply the existence of causality, which is better handled by the adoption of the ESR model in the estimation.

We employed econometric models to assess the factors influencing agricultural credit access and the impact on farm performance. We conducted the analysis in two stages. The first stage involved a direct examination of the determinants of crop productivity. The results highlight that factors such as area cultivated, types of fertilizer used, type of seeds used, irrigation, experience in farming, years of schooling, household assets, training rate, and household size play a crucial role in crop productivity.

On the second stage, we have had the impact of credit access on agricultural productivity, which makes the productivity gain evident. We further adopted the Propensity Score Matching (PSM) to analyze the relationship between credit access and farm performance.

The ESR model evaluates the impact of credit access on agricultural productivity using the Full Information Modified Likelihood (FIML). The results are summarized in Table 3. We see a good fit with independent variables with a significance of the likelihood ratio (LR) test of independence between the eqns. ($P < 0.01$). The estimated coefficient of correlation between credit access and agricultural productivity is positive and significantly different from zero, implying that self-selection occurred in credit access.

Table 3. Estimation results of the ESR model

Variables	Lnprdtyttalmrbkg_1	Lnprdtyttalmrbkg_0	Selection equation: CrdtAccess
Lntotal_acres	0.209***	0.145***	0.283***
total_asset	-0.000	0.000	-0.000
ImpvdSeds	0.079	0.095	-0.005
UsdChmcFert	0.107	0.193**	0.425**
UsdOgncFert	-0.131	-0.151	0.032
UsdHerbcides	0.498***	0.444***	2.633**
PrctIrgation	0.453	0.604**	-0.096
Lnfarmexper	-0.049	-0.048	-0.000
ExtnSevcVst	0.094	-0.037	0.006*
AccssdRoad	-0.001	-0.001**	0.021
DstncToFrm	-0.001	0.004**	-0.007
HhOwnRadio	0.084	0.256***	0.150
HhOwnTV	0.180*	-0.013	-0.001
HhAge	0.006	0.001	-0.062
HhGender	0.127	0.151	-0.231*
HhEdctn	0.018	0.006	0.060
HhMrtalSt	-0.001	-0.169	0.058
Lnhhsize	0.018	0.048	-0.074
_cons	5.633***	6.315***	-1.704***
/lns1 = -0.464***	/lns2 = -0.171***	/r1 = 0.148	/r2 = 0.987***
sigma_1 = 0.629	sigma_2 = 0.843	rho_1 = 0.146	rho_2= 0.756
Obs.	1042	1042	1042

LR test of indep. Eqns. chi2 (1) = 13.63 Prob > chi2 = 0.0002

Note: *, **, *** indicate significance at the 10%, 5%, and 1%, levels, respectively

Source: Field Survey (2018).

Cultivated area *(Lntotal_acres*) enables beneficiaries to gain 21 kg/acre and non-beneficiaries to gain 15 kg/acre. This would justify that beneficiaries of credit increase productivity per cultivated area. More importantly, cultivated areas without credit may not deliver the desired productivity due to a shortage of inputs that are easily acquired with credit access. In Ethiopia, cultivated area is negative and significantly related with crop productivity for both groups of farmers. May imply that the more the area is tilled, the more it requires financial support if it is missing farmers experience negative gain from the sown areas (Mukasa et al., 2017).

Improved seeds have a positive effect on agricultural productivity in both beneficiaries and non-beneficiaries. Though it is not statistically significant, the positive sign implies that improved seeds are important in increasing yields. The findings in this study are in line with the findings in Benin, which claim that improved seeds augment crop productivity, especially for farmers with credit because they can afford to get enough seeds for sowing (Acclassato et al., 2021).

The use of herbicides (*UsdHerbcides*) is positively and statistically significant in increasing productivity in two groups of farmers. Non-beneficiaries had their productivity increased by 55.9%, less than their counterparts, who increased their productivity by 64.5%. The same findings show that Ethiopian farmers use herbicides to deal with weeds in their farms (Mukasa et al., 2017).

Receiving agricultural information using television *(HhOwnTV)* statistically significantly influences crop productivity. Information through watching TV increases the crop productivity of the beneficiary farmers by about 19.7%. Through TV different programs such as edutainment about agricultural development, such as agricultural inputs to market networking. They demonstrate different agricultural practices on different crops as well as pastoralism that motivate and transform farmers. The results in this paper are in line with findings in Benin. The authors argue that the use of ICT improves the welfare of smallholder farm households in Benin (Armel Nonvide, 2023; Zhou et al., 2022; Yang et al., 2024).

The use of chemical fertilizers (UsdChmcFert) is positively and statistically significantly influencing crop productivity of non-beneficiaries. Producers who did not receive credit produced 21.3% more than those who did not use inorganic fertilizers. However, beneficiaries of credit do not increase productivity due to the use of inorganic fertilizers. It seems most of them opt to use herbicides to control the weeds in their plots/farms when they consider their plots are still fertile. Inorganic fertilizer is a commonly used input. In Ethiopia, it is used by farmers to boost their productivity (Mukasa et al., 2017).

Non-beneficiaries practicing irrigation in their plots/farms (PrctIrgation) benefit more than their counterparts. Irrigation is positively and statistically significantly related to the increase in agricultural productivity for non-beneficiaries. Irrigation increased productivity for 83% of non-beneficiaries. It seems beneficiaries of credit do not invest in irrigation systems or are more constrained. The establishment of an irrigation system is very expensive for a family and a small farming system. When they acquire small microloans/credit, they invest in other agricultural inputs such as seeds, herbicides, and labor.

The most practiced irrigation in the study area is along the basin when rivers or natural wells flow throughout the farming seasons. It seems non-beneficiaries base much on irrigation as an important determinant of crop productivity given that they do not access credit, which leads to their failure to use other agricultural inputs. The findings are in light of the findings obtained in Mukasa et al. (2017) that irrigation is crucial in boosting crop productivity and minimizing the climate-induced risks.

Using agricultural information received through *(HhOwnRadio*) is positively and statistically increasing crop productivity of non-beneficiaries. It increased productivity by 29.2% more than their counterparts. Just like using TV, through radio different programs about agricultural development are channeled to farmers via radio. Because most of these farmers dwell in rural areas, the most predominant source of information is radio. Just like in India, radio improves the welfare and productivity of farmers because they are educated about agriculture through radio (Vasudevan, 2023).

The analysis in this section elucidates the factors that influence agricultural productivity. However, the analysis does not reveal the impact and the gain from credit access. See Table 4 and Table 5, which present the estimated impact and gain in agricultural productivity, respectively. In Figure 3, the differences in agricultural productivity due to credit access are evident. Additionally, Figure 4 summarizes the differences in productivity between actual/real and their counterfactuals. Further, the study compares the average treatment effect on the treated (ATET), the average treatment effect on the not treated (ATENT), and the average treatment effect (ATE), which is defined as the difference between beneficiaries and non-beneficiaries (Bai et al., 2021 & 2023; Missiame et al., 2021; Ngoma, 2018)

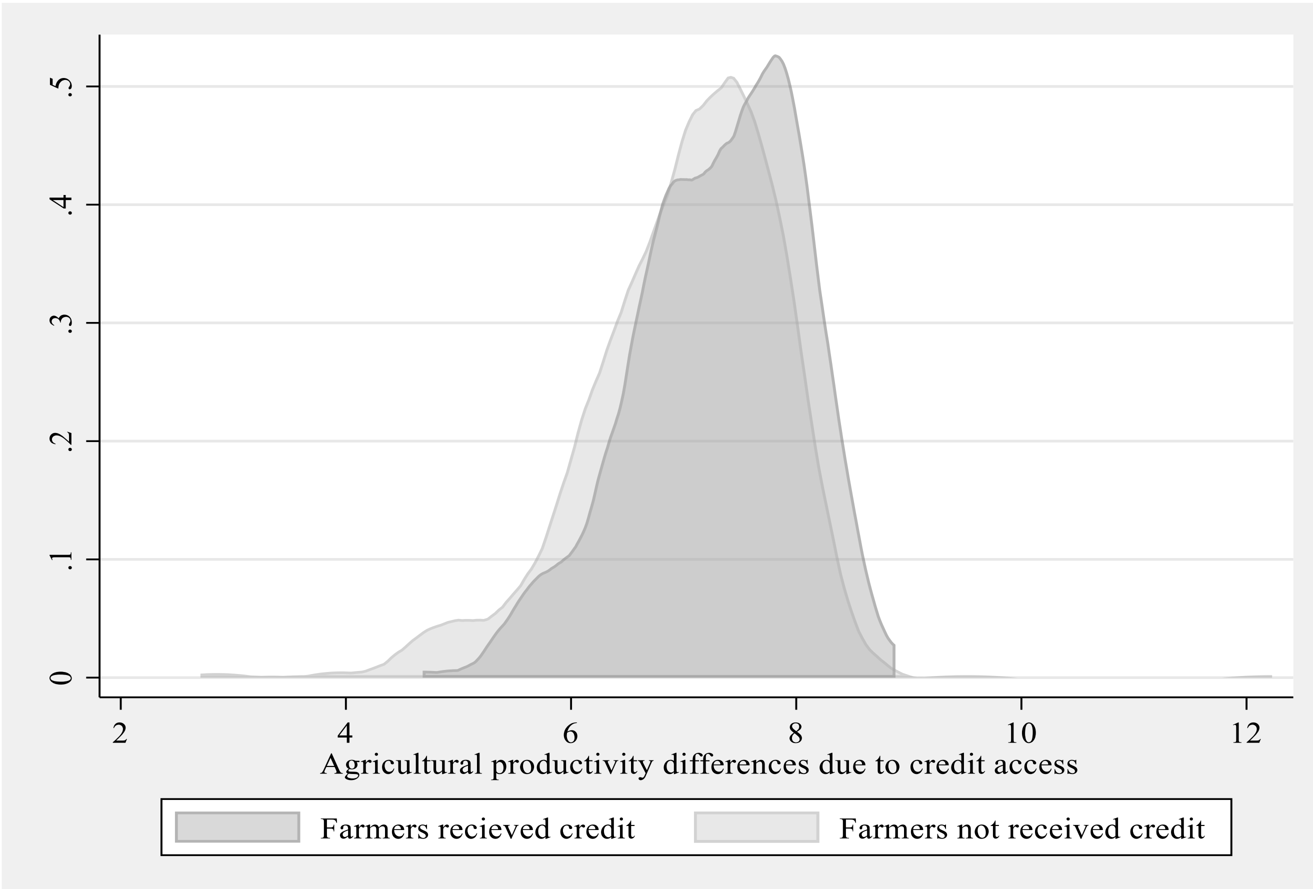

Figure 3. Difference in productivity due to credit access
Source: Field Survey (2018).

4.2. Impact of credit access on crop productivity

We used the ESR model to estimate the value of agricultural productivity for both groups of farmers. With the aid of Stata software, we obtained the impact of credit access on agricultural productivity. The agricultural productivity gain in this study is attained by reflecting the formula appearing in eqn. (xi). The same formula is used in Benin (Acclassato et al., 2021), Peru (Guirkinger & Boucher, 2008) and Ethiopia (Mukasa et al., 2017) to obtain the gain in agricultural productivity in a context of credit constraints.

By evaluating Figure 2, a clear difference between credit beneficiary and non-beneficiary small farmers can be seen. In Fig. 2, the dark pattern represents the crop productivity of beneficiary farmers (treated), whereas the light pattern depicts the productivity of non-beneficiaries (control). The farmers who received credit have the highest agricultural productivity in comparison with their counterparts. This difference is positive and statistically significant at the 1% level. The difference in crop productivity between the two groups is the exact effect of credit access (treated) on the farmers' productivity (treaties).

At first, on average, beneficiary and non-beneficiary farmers had positive agricultural productivity as well as their counterfactuals. Implying that even in a context without credit, still all on average would get positive yields from their plots/farms. After the intervention (credit access), treated small farmers had the highest agricultural productivity of about 7.302 kg/acre, and their counterfactual beneficiaries had about 6.759 kg/acre. Credit access beneficiaries have more crop productivity, with a difference of about 0.534 kg/acre. The agricultural productivity gain is about 8.03%.

For the farmers who did not receive credit, their crop productivity is 6.997 kg/acre, and for their counterfactual beneficiaries (what if received credit), their crop productivity is 8.053 kg/acre. The findings further entail that if farmers who did not receive credit for agriculture were given such credit and invested it in agricultural activities, they would produce more than their current crop productivity for a 15.09% increase.

The crop productivity in this study as the impacts of credit access is in the light of other findings in other places, such as in Benin, where a study obtained a gain of 15% (Acclassato et al., 2021). In Peruvian agriculture the gain was between 49% and 59% (Guirkinger & Boucher, 2008), and in Ethiopia, the gain was 60.03% (Mukasa et al., 2017). Productivity gains for both actual (treated) and counterfactuals are high and significant. Promoting and enhancing credit access for non-beneficiary farmers would significantly improve their agricultural productivity without abandoning the continuation of credit support to the treated farmers.

We considered other estimations, such as PSM, as a comparison of the results from the ESR model. At least the results from both models are consistent. Agricultural financing in Tanzania is relatively profitable. The study provides evidence-based insight that the public and private sectors provide and guarantee the Tanzanian smallholder farm household access to credit is not superfluous.

Table 4. Estimated Agricultural Productivity

Credit access (CrdtAccess) status	Productivity (Mean)
Received Credit (EY1)	7.302
Counterfactual (EY12)	6.759
Not Received Credit (EY0)	6.997
Counterfactual (EY01)	8.053

Source: Field Survey (2018).

Table 5. Impact of credit access in agricultural productivity

Nature of farmers	Productivity with access to credit	Productivity Counterfactual with access to credit	Impact of Credit Access on Productivity	Productivity gain
Treated	i. 7.302	ii. 6.759	0.543***	8.03%
Untreated	iii. 8.053	iv. 6.997	1.056***	15.09%

Note: *, **, *** indicate significance at the 10%, 5%, and 1%, levels, respectively.
ATET (i-ii), ATENT (iii-iv) and ATE (ATET-ATENT), respectively.
Source: Field Survey (2018).

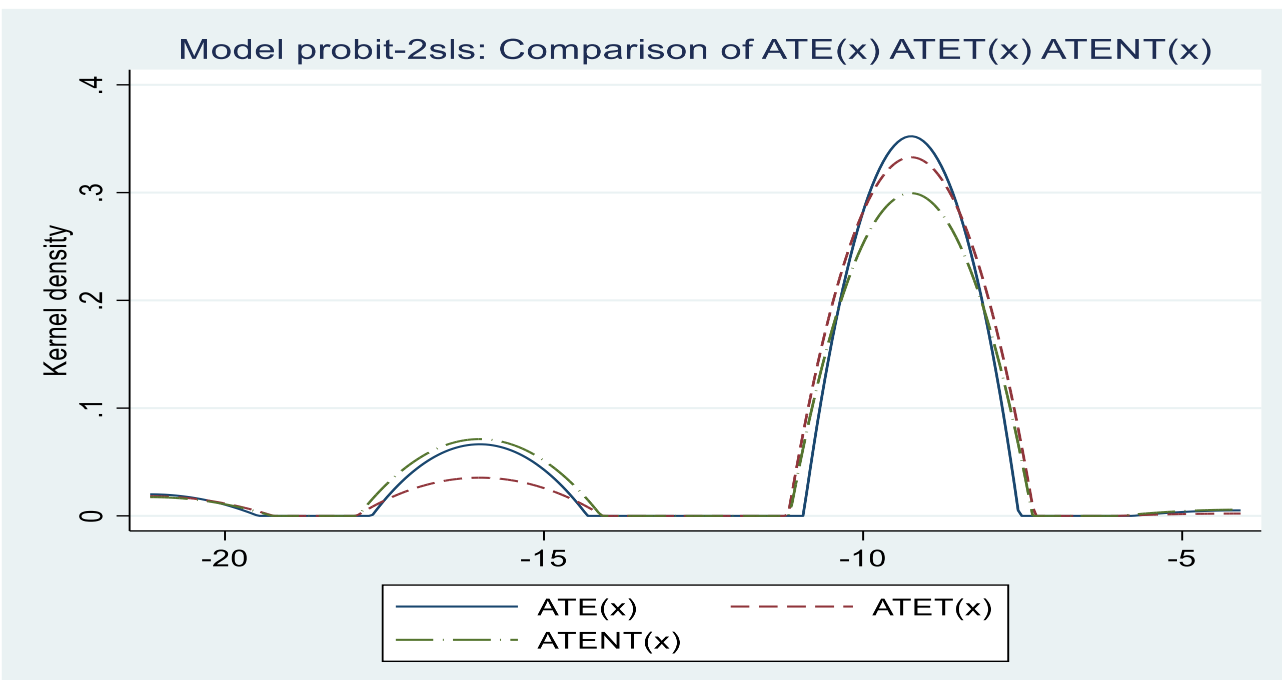

Figure 4. Comparison of ATET, ATENT and ATE
Source: Field Survey (2018).

4.3. Robust check

The PSM technique enables us to balance the distribution of covariates across farmers with and without credit so that the effect of credit can be evident. It was important in comparing the effectiveness of credit among farmers. It was necessary to control the weakness of impact measuring techniques by controlling the confounding variables. The confounding variables (covariates) may lead to biased mean comparison of credit (hereof treatment) and control groups. PSM here serves as a comparison to ESR's results, which are more powerful in addressing the endogeneity and sample selection bias in impact assessment studies (Lokshin & Sajaia, 2004; Ma et al., 2018).

In both estimation techniques the differences in mean comparison between access to credit and their counterfactual are evident. They confirm the impact of credit access on agricultural productivity. See Table 4, Table 5, and Figure 3, which display the impact of credit access on crop productivity as estimated from the ESR model. For the comparison check from PSM results, Table 6 and Figure 5 summarize the results.

Table 6. Estimation results of the PSM model: Treatment-effects estimation (Yield effects)

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
Lnprdtyttalmrbkg	Unmatched	7.302	7.005	0.297	0.060	4.930
	ATT	7.302	6.942	0.360	0.142	2.530

Source: Field Survey (2018).

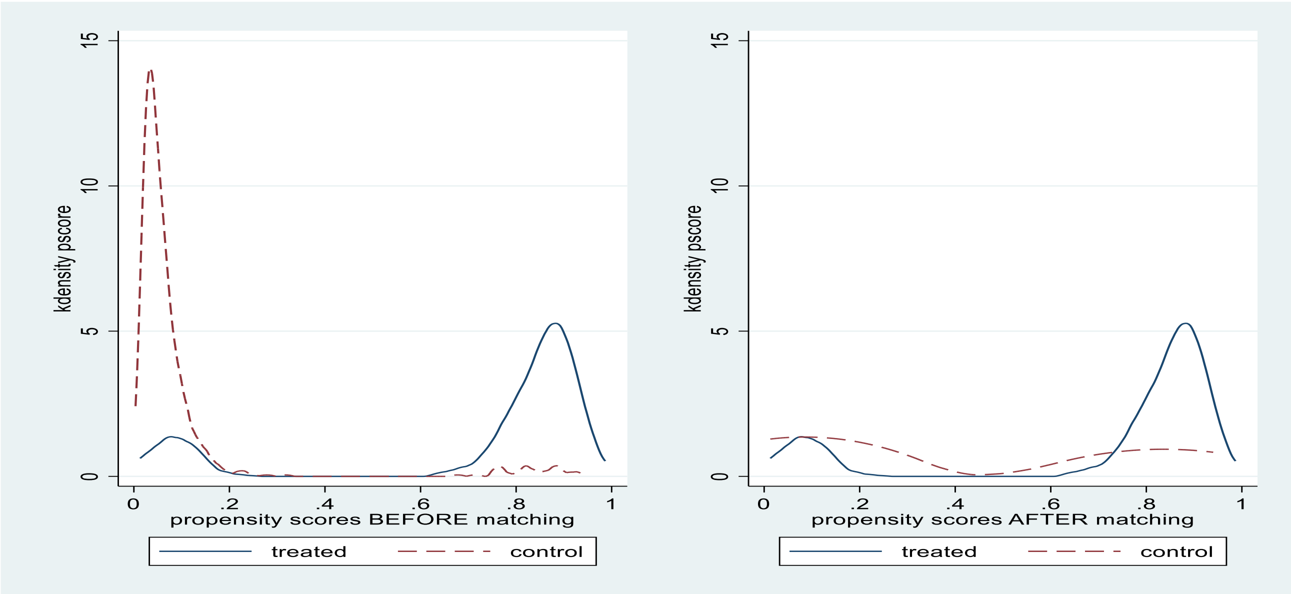

Figure 5. Propensity Score Matching (PSM)
Source: Field Survey (2018).

5. Conclusion and policy implications

This study examined the accessibility of agricultural finance and its effects on the agricultural output of smallholder farmers. Descriptive analysis highlighted the causes of credit denial for smallholder farmers and why some never seek credit. The two main causes of credit application rejection are a lack of collateral (61.76%) and proper documents (14.71%). However, risks associated with credit (22.51%), lack of knowledge of how to get credit (19.44%), too high interest rates (13.81%), the perception that it is very difficult to get credit (13.04%), financial institutions not being available (2.81%), and some not wanting credit (20.84%) deter some from applying for credit.

In the regression analysis, the paper employed the ESR model. PSM was adopted for comparison and consistency check of the results. The ESR model enabled the study to examine the factors that are directly related to credit access, crop productivity, and the impact of credit access (as a proxy of agricultural finance) on crop productivity. The covariates that are directly driving agricultural productivity of beneficiaries and non-beneficiaries include cultivated areas, use of herbicides and inorganic fertilizers, using media (TV and radio) programs related to agricultural practices, irrigation, distance to the farm, and access to the market.

The impact analysis elucidates that the beneficiaries gained more than the non-beneficiaries by 8.03%. Non-beneficiaries would increase their crop productivity by 15.09% if there were no credit constraints on them. At least credit access as a proxy of agricultural finance does not change its significance in crop productivity even in the presence of covariates in ESR and PSM analyses.

A considerable number of policy implications are emanating from the results in favour of Tanzanian smallholder farmers financing. One of the major challenges to the public and private sectors is financing agriculture through smallholder farmers. The findings may draw attention and be a turning point for the consideration of smallholder farmers, that if they are supported financially, they can be very productive.

The orientation of different programs supporting smallholder farmer households since they form a large and significant segment of the farming population. It would be better for public and private sectors to be well operated in favour of smallholder farmers. For instance, the government can regulate the interest rate on the supply side, enabling farmers' land or assets to be bankable collaterals. On the demand side, financial awareness about financial products and services, transaction costs, and risk perception are crucial in facilitating credit access. Farmers will easily access credit that will enhance optimal uptakes of agricultural input. Also, they will be able to shift from the application of rudimentary tools to modern technologies of farming.

A positive and statistically significant cultivated area, especially for credit beneficiaries compared to non-beneficiaries, may imply that credit access is important to be able to meet other farm inputs in the processes of farm management, such as farm preparation, planting, weeding, harvesting stages, paying labourers, and buying improved seeds and herbicides, which would increase cultivated areas and augment more crop productivity.

The use of inorganic fertilizers and herbicides is positive and statistically significantly related to smallholder farmers' agricultural productivity. They are very expensive for smallholder farmers who are already constrained in terms of resources to invest in crop farming. However, they are must-have inputs for increased crop productivity, especially for infertile plots/farms. Resources such as credit to farmers are very crucial to afford the costs associated with the use of these inputs. The results imply that the government should increase subsidies for these important inputs to enable smallholder farm households to augment their productivity.

Irrigation is positively and statistically significant, influencing the productivity of the non-beneficiaries, which might have implied that if they faced no credit constraints, they would increase the uptake of other inputs in their plots/farms, and their productivity would be augmented more than the current level of productivity. With climate-induced stress and risks caused by variability in temperature and rain patterns. Reliable irrigation systems can reduce the risks of such crop failures.

The findings may imply that TADB, as a public bank, should diversify their financial products and services to favour small-scale farmers cultivating crops rather than supporting only the agro-processing agricultural sub-sector. The great efforts of small-scale farmers can be supported through financial markets. Public and private support programs focus on promoting, facilitating, and enhancing agricultural financing.

The targets can be increasing crop productivity and risk management ability that would greatly contribute to agricultural transformation from merely subsistence to market-oriented agriculture. Modern and attractive agriculture will be a reality for different age groups. Food security and income will be improved, poverty will be reduced, and inclusive economic growth as a purview of SDGs will be achieved.

6. Declarations

Author contribution statement

Yohane Kitwima Magembe: Comprehended and designed the study; analyzed and interpreted the data, materials, analysis tools, and writing the paper. Martin Bai: Proofreading, editing, grammar, and setup.

Funding statement

No funding received for this work.

Ethical declaration

This paper uses secondary data. At the time of data collection, clearance and permission from relevant authorities and informed consent from respondents were seriously adhered to.

Data availability statement

Data is available upon request.

Competing Interest

We declare no known competing interests.

Additional information

No extra information is available for this paper at present.

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References

Acclassato, D., Goudjo, G. G., & Senou, M. M. (2021). Access to finance and difference in family farm productivity in Benin: Evidence from small farms. *Scientific African*, *13*, e00940. https://doi.org/10.1016/j.sciaf.2021.e00940

Adamon N. Mukasa, Anthony M. Simpasa, and A. O. S. (2017). *Credit constraints and farm productivity: Micro-level evidence from smallholder farmers in Ethiopia. Working Paper Series No. 247. African Development Bank Group* (Issue 247, pp. 1–40).

Agbodji, A. E., & Johnson, A. A. (2019). Agricultural Credit and Its Impact on the Productivity of Certain Cereals in Togo Agricultural Credit and Its Impact on the Productivity of Certain Cereals in Togo. *Emerging Markets Finance and Trade*, *0*(0), 1–17. https://doi.org/10.1080/1540496X.2019.1602038

Akter, A., Geng, X., Endelani, G., Lu, H., Hoque, F., Kiraru, M., & Abbas, Q. (2022). Climate

Risk Management Income and yield effects of climate-smart agriculture (CSA) adoption in flood prone areas of Bangladesh : Farm level evidence. *Climate Risk Management*, *37*, 100455. https://doi.org/10.1016/j.crm.2022.100455

Ali, D. A., Deininger, K., & Duponchel, M. (2014). Credit Constraints and Agricultural Productivity : Evidence from rural Rwanda. *The Journal OfDevelopment Studies*, *50*(5), 649–665. https://doi.org/10.1080/00220388.2014.887687

Areal, F. J., Clarkson, G., Garforth, C., Barahona, C., Dove, M., & Dorward, P. (2020). Does TV edutainment lead to farmers changing their agricultural practices aiming at increasing productivity? *Journal of Rural Studies*, *76*(September 2019), 213–229. https://doi.org/10.1016/j.jrurstud.2020.03.001

Armel Nonvide, G. M. (2023). Impact of information and communication technologies on agricultural households' welfare in Benin. *Telecommunications Policy*, *47*(6), 1–10. https://doi.org/10.1016/j.telpol.2023.102570

Assouto, A. B., Houngbeme, D. J., Assouto, A. B., & Houngbeme, D. J. (2023). Cogent Economics & Finance Access to credit and agricultural productivity : Evidence from maize producers in Benin Access to credit and agricultural productivity : Evidence from maize producers in Benin. *Cogent Economics & Finance*, *11*(1). https://doi.org/10.1080/23322039.2023.2196856

Balana, B. B., Mekonnen, D., Haile, B., Hagos, F., Yimam, S., & Ringler, C. (2022). Demand and supply constraints of credit in smallholder farming : Evidence from Ethiopia and Tanzania. *World Development*, *159*, 106033. https://doi.org/10.1016/j.worlddev.2022.106033

Blazquez-Soriano, A., & Ramos-Sandoval, R. (2022). Information transfer as a tool to improve the resilience of farmers against the effects of climate change: The case of the Peruvian National Agrarian Innovation System. *Agricultural Systems*, *200*(April), 103431. https://doi.org/10.1016/j.agsy.2022.103431

Bonnke, S. M., Martin, P., Nguezet, D., Nyamugira, A., Jean-jacques, M. S., & Manyong, V. (2022). *Farmers ' credit access in the Democratic Republic of Congo : Empirical evidence from youth tomato farmers in Ruzizi plain in South Kivu Farmers ' credit access in the Democratic Republic of Congo : Empirical evidence from youth tomato farmers in Ruzizi p*. *May*. https://doi.org/10.1080/23322039.2022.2071386

Chandio, A. A., Jiang, Y., & Rehman, A. (2021). *Does Formal Credit Enhance Sugarcane Productivity ? A Farm-Level Study of Sindh , Pakistan*. https://doi.org/10.1177/2158244020988533

Christiaensen, L., & Martin, W. (2018). Agriculture, structural transformation and poverty reduction: Eight new insights. *World Development*, *109*, 413–416. https://doi.org/10.1016/j.worlddev.2018.05.027

Converse et al. (2012). *Credit Rationing in Markets with Imperfect Information By Joseph E. Stiglitz and Andrew Weiss. Presented by Lara Converse, Elyas Fermand, Aditya Rachmanto, and Annie Tao January 24, 2012* (pp. 1–27).

FAO. (2010). The State of Food Insecurity in the World Addressing food insecurity in protracted crises 2010 Key messages. In *Notes*.

FAO. (2015). *The economic lives of smallholder farmers* (p. 48).

FAO. (2018). Global Forum on Food Security and Nutrition Youth employment in agriculture as a solid solution to ending hunger and poverty in Africa. In *Global Forum on Food Security and Nutrition* (pp. 1–9).

Farrell, M. J. (1957). The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society.*, *120*(3), 253–290.

Finn R. Forsund, C.A. Knox Lovell, P. S. (1980). A survey of frontier production functions and of their relationship to efficiency measurement. *Journal of Econometrics*, *13*(1), 5–25.

Fishburn, P. C. (1970). Utility Theory for Decision Making. In *Rcsarch Analysis Corporation*.

Gikonyo, N. W., Busienei, J. R., Gathiaka, J. K., & Karuku, G. N. (2022). Analysis of Household Savings and Adoption of Climate Smart Agricultural Technologies. Evidence from Smallholder Farmers in Nyando Basin, Kenya. *HELIYON*, e09692. https://doi.org/10.1016/j.heliyon.2022.e09692

Girma, Y. (2022). Credit access and agricultural technology adoption nexus in Ethiopia : A systematic review and meta-analysis. *Journal of Agriculture and Food Research*, *10*(March), 100362. https://doi.org/10.1016/j.jafr.2022.100362

Guirkinger, C., & Boucher, S. R. (2008). Credit constraints and productivity in Peruvian agriculture. *Agricultural Economics*, *39*(3), 295–308. https://doi.org/10.1111/j.1574-0862.2008.00334.x

Heckman, J. J. (2001). Econometrics and empirical economics. *Journal of Econometrics*, *100*(1), 3–5. https://doi.org/10.1016/S0304-4076(00)00044-0

Hu, L., Lopez, R. A., & Zeng, Y. (2019). The impact of credit constraints on the performance of Chinese agricultural wholesalers. *Applied Economics*, *0*(0), 1–12. https://doi.org/10.1080/00036846.2019.1584385

Hu, Y., Liu, C., & Peng, J. (2021). Financial inclusion and agricultural total factor productivity growth in China. *Economic Modelling*, *96*(November 2020), 68–82. https://doi.org/10.1016/j.econmod.2020.12.021

Jelsma, I., Woittiez, L. S., Ollivier, J., & Dharmawan, A. H. (2019). Do wealthy farmers implement better agricultural practices? An assessment of implementation of Good Agricultural Practices among different types of independent oil palm smallholders in Riau, Indonesia. *Agricultural Systems*, *170*(November 2018), 63–76. https://doi.org/10.1016/j.agsy.2018.11.004

Lokshin, M., & Sajaia, Z. (2004). Maximum Likelihood Estimation of Endogenous Switching Regression Models. *The Stata Journal: Promoting Communications on Statistics and Stata*, *4*(3), 282–289. https://doi.org/10.1177/1536867x0400400306

Lorenzo Cotula; Sonja Vermeulen; Rebeca Leonard; James Keeley. (2009). Land Grab or Development Opportunity?, IIED / FAO / FIDA, London /Rome, 2009, p. 130 . In *The*

Journal of pharmacy and pharmacology: Vols. 27 Suppl?- (p. 130).

Lovell, C. A. K. (1993). The measurement of productive efficiency: techniques and applications. In *Oxford University Press, Oxford* (pp. 1–21).

Ma, W., Renwick, A., & Bicknell, K. (2018). *Higher Intensity , Higher Profit ? Empirical Evidence from Dairy Farming in New Zealand*. https://doi.org/10.1111/j.1467-6419.2007.00503.x

Maddala, G. S. (1986). *Limited-dependent and qualitative variables in Econometrics. The University of Cambridge Press 1986, New York, USA* (A. D. D. M. H. Sonnenschein (ed.)).

Mishra, A. K., Louhichi, K., Genovese, G., & Gomez y Paloma, S. (2023). Insights into land size and productivity in Ethiopia: What do data and heterogenous analysis reveal? *Frontiers in Sustainable Food Systems*, *7*. https://doi.org/10.3389/fsufs.2023.1057674

Missiame, A., Nyikal, R. A., & Irungu, P. (2021). What is the impact of rural bank credit access on the technical efficiency of smallholder cassava farmers in Ghana? An endogenous switching regression analysis. *Heliyon*, *7*(5), e07102. https://doi.org/10.1016/j.heliyon.2021.e07102

Mohammed Seidu, M., & Tanko, M. (2022). Maize productivity amidst northern rural growth credit programme in Ghana. *Heliyon*, *8*(9), e10420. https://doi.org/10.1016/j.heliyon.2022.e10420

Nakano, Y., & Magezi, E. F. (2020). The impact of microcredit on agricultural technology adoption and productivity : Evidence from randomized control trial in Tanzania. *World Development*, *133*, 104997. https://doi.org/10.1016/j.worlddev.2020.104997

Ngoma, H. (2018). *Does minimum tillage improve the livelihood outcomes of smallholder farmers in Zambia ?* 381–396.

Nikam, V., Ashok, A., & Pal, S. (2022). Farmers' information needs, access and its impact: Evidence from different cotton producing regions in the Maharashtra state of India. *Agricultural Systems*, *196*(March 2021), 103317. https://doi.org/10.1016/j.agsy.2021.103317

Ogada, M. J., Radeny, M., Recha, J., & Dawit, S. (2021). Adoption of complementary climate - smart agricultural technologies : lessons from Lushoto in Tanzania. *Agriculture & Food Security*, 1–10. https://doi.org/10.1186/s40066-021-00321-w

Osabohien, R., Mordi, A., & Ogundipe, A. (2020). Access to credit and agricultural sector performance in Nigeria. *African Journal of Science, Technology, Innovation and Development*, *0*(0), 1–9. https://doi.org/10.1080/20421338.2020.1799537

Rada, N. E., & Fuglie, K. O. (2019). New perspectives on farm size and productivity. *Food Policy*, *84*(March 2018), 147–152. https://doi.org/10.1016/j.foodpol.2018.03.015

Ramgopaul Roop, Miles Weaver, A. P. F. & M. M. (2023). Innovative Approaches in Smallholder Farming Systems to Implement the Sustainable Development Goals. In *SDGs in the Americas and Caribbean Region* (pp. 1–28).

Rasheed, A., Mwalupaso, G. E., Abbas, Q., & Tian, X. (2020). Women Participation : A

Productivity Strategy in Rice Production. *Sustainability*, *12*, *2870*.

Rashid, F. N. (2021). Resources , Conservation & Recycling ACHIEVING SDGs in TANZANIA : Is there a nexus between land tenure SECURITY , agricultural credits and rice PRODUCTIVITY ? *Resources, Conservation & Recycling*, *164*(September 2020), 105216. https://doi.org/10.1016/j.resconrec.2020.105216

Sakketa, T., & Gerber, N. (2017). Rural Shadow Wages and Youth Agricultural Labor Supply in Ethiopia: Evidence from Farm Panel Data. *SSRN Electronic Journal*, *236*. https://doi.org/10.2139/ssrn.2956283

Salima, W., Manja, L. P., Chiwaula, L. S., & Chirwa, G. C. (2023). The impact of credit access on household food security in Malawi. *Journal of Agriculture and Food Research*, *11*(November 2022), 100490. https://doi.org/10.1016/j.jafr.2022.100490

Stiglitz, J. E., & Weiss, A. (1981). Credit Rationing in Markets with Imperfect Information Joseph E . Stiglitz ; Andrew Weiss. *The American Economic Review*, *71*(3), 393–410.

TADB. (2020). *TANZANIAN AGRICULTURAL DEVELOPMENT BANK (T) LTD Publication of Financial Statements for First Quarter Ended 31st March 2020 Smallholder Credit Guarantee Scheme (SCGS) Performance* (Issue March, p. 2963849).

Tanzania National Council for Financial Inclusion (TNCFI). (2017). National Financial Education Framework 2016 - 2020 2017 re-print. In *Finance Research Letters* (1st ed., Vol. 8, Issue 2, p. 40). Elsevier Inc. https://doi.org/10.1016/j.jcorpfin.2020.101831

Tripathi, A. K. (2017). Credit for Agricultural Households in India: Growing Inequities. *Journal of Asian and African Studies*, *52*(6), 807–823. https://doi.org/10.1177/0021909615618983

UN. (2015). *Sustainable Development Goals (SDGs)* (Vol. 11, Issue 1, pp. 1–14).

URT. (2016). National Strategy for Youth Involvement in Agriculture. In *Ministry of Agriculture Livestock and Fisheries* (pp. 2016–2021).

Vasudevan, S. (2023). Radio and technology adoption during India's Green Revolution: Evidence from a natural experiment. *World Development*, *161*, 106069. https://doi.org/10.1016/j.worlddev.2022.106069

Wim, Meeusen & Julien, van D. B. (1977). Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. *International Economic Review*, *18*(2), 435–444.

Yami, M., Feleke, S., Abdoulaye, T., Alene, A. D., Bamba, Z., & Manyong, V. (2019). African Rural Youth Engagement in Agribusiness : Achievements , Limitations , and Lessons. *Sustainability*. https://doi.org/10.3390/su11010185

Chapter 5

Summary and Conclusion

The thesis consists of three themes presented in four essays/papers that focus on addressing the problems such as climate change impacts, youth unemployment, and agricultural finance constraints. The themes are CSA technologies, youth involvement in agricultural activities, and agricultural finance. Addressing the problems enhances transforming the African agrarian economy, which is a megatrend agenda in Africa. Subsequently, achieving some of the SDGs, such as ending hunger and poverty, mitigating climate change impacts, and promoting inclusive economic growth and decent job creation for all (UN, 2015).

There is one paper presented in the second chapter. It investigates the impact of CSA integration in farming on crop productivity and income by smallholder farmers using secondary data from the National Sample Census of Agriculture (NSCA) of 2020 of Tanzania. The paper highlights the important role of CSA technologies in augmenting both crop productivity and income.

Chapter three contains two papers. Paper one in chapter three focuses on the problems and challenges that discourage youth involvement in agriculture. Further, the paper investigates the drivers that influence youth intensity of participation in agricultural activities. Paper two in chapter three examines the impact of youth intensity of participation in agriculture on farm performance. We adopt a doubly robust IPWRA estimator backed by PSM and ESR models in examining a sample of 3399 youth cultivating less than 2 hectares.

The fourth chapter includes one paper. The paper reveals the role of agricultural finance in improving crop productivity among credit-constrained smallholder farmers. The paper mainly seeks answers to questions such as why there are agricultural credit constraints? Do unconstrained smallholder farmers harvest more than their counterparts? The findings confirm that credit unconstrained farmers augment crop productivity. Interestingly, even the constrained farmers would increase their crop harvests by 15.9% if no credit constrained is assumed.

The key findings from this thesis include:

a. Factors such as land size, education, adult males, credit access, off-farm income, distance to the market, and farm ownership are crucial determinants of CSA application on farms. They play a great role in boosting both crop productivity and income as covariates in the model.

b. Surprisingly, seeds and herbicides do not promote crop productivity. It may imply that the government needs to be cautious of the types of seeds provided. It may imply that many resource-poor farmers still use traditional seeds, which are not climate tolerant causing a decline in harvests.

c. CSA technologies adopters increase crop productivity compared to non-CSA adopters

d. CSA technologies augment the income of households that adopted CSA more than their counterparts.

e. If non-CSA technologies adopters had they adopted, would improve their crop harvests.

f. If non-CSA technologies adopter had they adopted, would improve their incomes.

g. On youth involvement in agriculture, the thesis reports the critical problems that discourage youth involvement in agriculture. The critical ones include unreliable rainfall associated with floods, pests or diseases, and prolonged drought.

h. The critical challenges encountered by youth in the sector include low market prices, limited crop markets access, poor roads and high transport costs, no reliable crop buyers, and lack of market information.

i. Factors such as access and usage of farm tools (e.g., tractors), profits, access and usage of irrigation facilities, doing agro-processing, land ownership, access to agricultural credits, membership in farmers' cooperatives and organizations, access to agricultural extension services, use of information source channels (e.g., radio, TV, and the internet), and distance to the nearest market are positively and statistically significantly explaining youth intensity of participation in agricultural activities.

j. Further, the thesis reports factors such as general education and off-farm income are negatively and statistically significantly influencing youth intensity of engagement in agriculture. As youth get more education, it reduces the propensity of full-time involvement in agriculture. The same when they have access to off-farm income generating jobs, they tend to abandon agricultural activities.

k. Youth intensive involvement in agriculture augments farm performance. We proxied farm performance by maize yields, net returns, and returns on investment (ROI). The empirical results from IPWRA, ESR, and PSM report that intensive engagement increased all three outcomes.

l. Upon examination of agricultural finance, the results indicate that the causes of credit denial for smallholder household farmers are lack of collateral and improper documents.

m. We further examined why some small-scale farmers never seek agricultural credit while they are resource constrained. The critical reasons include the anticipated risks associated with credit access, lack of knowledge on how to get credit, too high interest rates, the perception that it is very difficult to get credit, and financial institutions not being available.

n. Factors such as owning land, access to extension services, and using farm inputs such as chemical fertilizers and herbicides increase the propensity of accessing credit.

o. The covariates that are directly driving crop productivity of beneficiaries and non-beneficiaries include cultivated areas, use of herbicides and inorganic fertilizers, using media (TV and radio), irrigation, distance to the farm, and access to the market.

p. In impact analysis, the paper on credit access reveals that the beneficiaries gained more than the non-beneficiaries by 8.02%. Non-beneficiaries would increase their crop productivity by 15.09% if there were no credit constraints on them. At least credit access as a proxy of agricultural finance does not change its significance on crop productivity even in the presence of covariates that have confounding effects on the agricultural productivity in ESR after a series of robustness checks.

Furthermore, the findings are detailed in parts 5.1 to 5.3, whereas section 5.4 reports the thesis' contributions and implications of the findings. Part 5.5 presents the limitations and suggests future ventures for research.

5.1. Main findings of Chapter 2

There is a growing strand of research on CSA technologies integration in agriculture to serve the three pillars of productivity, mitigation, and resilience. However, the impact of CSA adoption on smallholder farms' crop productivity and income is not fully presented, especially in the Tanzanian context.

Chapter 2 investigates the impact of CSA adoption on farm productivity and income for smallholder farmers. The first paper, *"Climate-Smart Agriculture and the Economics of Crop Productivity in Tanzania,"* investigates the impact of CSA adoption on crop productivity and income using the National Sample Census of Agriculture (NSCA) of 2020 of Tanzania.

In the current literature there is several research about CSA adoption in Tanzania. There are several studies examined CSA practices and CSA usage determinants (Bongole et al., 2020; Elizabeth et al., 2021; Kurgat et al., 2020; Ogada et al., 2021; Shemsanga et al., 2010; Teklewold et al., 2020). Further, Bongole et al. (2022) assessed the impact of CSA on households food security, and Nyasimi et al. (2017) assessed the barriers to adopting CSA. The extant studies do not investigate the effect of CSA adoption on grains and legume productivity and income.

Although there are some studies investigating the impacts of CSA technologies integration on farm productivity and income in other places, such as Bangladesh (Akter et al., 2022), the impact of CSA on maize productivity and income in Malawi and Zambia (Murray et al., 2016; Abdulai, 2016; Amadu et al., 2020a; Kuntashula et al., 2014; Amadu et al., 2020a), and in Ethiopia, the determinants and effects of CSA on farms (Belay et al., 2022; Berger et al., 2017; Dercon & Christiaensen, 2011; Habtewold, 2021; Kifle et al., 2022; Teklewold et al., 2013).

The literature beyond the African context reveals that climate change impacts and hazards have attracted cardinal research, and the strand is soaring across the globe. For instance, in Europe with a case study in Italy, Coderoni & Pagliacci (2023) investigated the use of CSA and the effect on Italian farms. In China, Feng et al. (2023) assessed the impact of CSA on maize production while minimizing carbon footprint. In Asia with evidence from India, Jena et al. (2023) examined the determinants of CSA, resilient practices, and their effect on yield and household income, whereas Rodríguez-Barillas et al. (2024) assessed how CSA acceptance is a driver of farmers' behaviour, policy consistency, and comprehensiveness in Latin America.

The previous literature highlights that successful CSA adoption, improved crop yield, increased income, and reduced poverty among adopters. Whilst prior studies have well documented the usage, applications, determinants, and barriers of CSA practices, there has been no prior research that investigates the crucial role of CSA in boosting crop productivity and augmenting income of small-scale farmers cultivating less than 2 hectares in Tanzania. It is unclear whether the findings in the existing studies are sample-specific or driven by other factors, as the climate change impacts and their adaptation strategies are location-specific (Ngaiwi et al., 2023).

This study adds to the empirical literature by analyzing the impact of CSA technologies adoption on crop productivity and household income among smallholder farmers who occupy a larger segment of the farming population. Further analysis reveals that smallholder farmers adopting CSA increase crop (maize, paddy, and beans) productivity and augment their household's income.

Interestingly, non-adopters would significantly improve their crop productivity and income. The findings in this paper affirmed that CSA improves crop yield and increases income that can lead to poverty reduction and improve food security.

This paper suggests that covariates such as land size, input costs, distances to the market, and home contribute a significant propensity to crop production per farm for both adopters and non-adopters.

The findings in this paper are consistent with other findings elsewhere (Akter et al., 2022; Murray et al., 2016; Abdulai, 2016; Amadu et al., 2020a; Kuntashula et al., 2014; Amadu et al., 2020a).

5.2. Main findings of Chapter 3

Chapter 3 includes two research papers. The first paper in this chapter is entitled *"Drivers of Youth Intensity of Participation in Agriculture: Insights from Tanzania."* The paper investigates youth intensity of involvement in agricultural-related activities.

Previous literature reveals that youth participation or negligence in agricultural activities is caused by either positive or negative perceptions that persist about agriculture (Henning et al., 2022). If youth live or are nurtured in agricultural supporting environments, they will develop positive perceptions and be good farmers while negatively rewarding environments discourage youth participation in agriculture (Maritim, 2020; Magagula & Tsvakirai, 2020; Heifer International, 2021; Sumberg et al., 2017).

Several studies discuss youth involvement in agricultural activities because they consider agriculture profitable and are supported to fully participate in agriculture (Blattman & Jeannie Annan, 2011; Henning et al., 2022; Kaki et al., 2022; Kalya Dennis Maritim, 2020; Karen Brooks, Sergiy Zorya, Amy Gautam & Goyal, 2013; Magagula & Tsvakirai, 2020; Muthomi, 2017; Unity, Chifupa & Aluwani, 2021; Yami et al., 2018; Zidana et al., 2020).

Other studies focus on the idea that negative perceptions lead to youth negligence in agriculture (August, 2020; Blattman & Jeannie Annan, 2011; Heifer International, 2021; Henning et al., 2022; Janzen, 2014; Kalya Dennis Maritim, 2020; Karen Brooks, Sergiy Zorya, Amy Gautam & Goyal, 2013; Losch, 2016; Lucy Karega Njeru, 2017; Magagula & Tsvakirai, 2020; Martinson, A. T., Yuansheng, J., & Monica, 2019; Mcmullin, 2022; Mengistu, 2017; Sumberg et al., 2017; The Alliance for a Green Revolution in Africa (AGRA), 2019; Chifupa & Aluwani, 2021; Wole-Alo I. Felicia, Falase O. Emmanuel, 2016; Wuni et al., 2017; Yami et al., 2018).

The negative perceptions, complemented with hurdles facing agricultural activities such as climate change and soaring population, intensify the problem of low youth buy-in in agriculture. Youths keep neglecting agricultural activities, despite the endless efforts to get youths fully involved in agricultural-related activities (Kafle et al., 2019).

The impacts of youth ignoring agriculture are manifesting such as youth unemployment which in turn significantly threatens social cohesion and political stability, such as rebel movement motivation (e.g., in Ethiopia in 2016), acts of terror (e.g. in Kenya) (The Alliance for a Green Revolution in Africa (AGRA), 2019), and increases in crime rates and substance abuse, urban gangs, political unrest, and increased illegal migration to wealthier nations (World Bank (WB), 2011). Eventually, the agriculture sector has been under the control of elders at an average age of 60 years (Guo et al., 2015) who are economically unstable in terms of power and resource mobilization (FAO, 2014) and weak performance of the sector that contributes less to GDP. Also, food insecurity and poverty are persistent (URT, 2022a).

The previous studies rarely examined what exogenous factors nurture youths' perceptions towards agricultural-related activities. To fill the gap, this paper first investigates the critical problems and challenges youth face in agriculture. Secondly, examine the drivers of youth perceptions towards agriculture. The paper answers important questions for policymaking, such as "what nurtures youths' perceptions about the intensity of participation in agriculture?" A proper answer to this question will enable policymakers to have in place viable policy and program measures to increase and retain youth in the agricultural sector.

The results show that the reported critical problems facing youth include unreliable rainfall and floods, plant pests or/diseases, and prolonged drought, which are associated with climate change impacts.

The critical challenges include low market prices, markets are too far, rough roads and high transport costs, no crop buyers, and lack of market information.

The empirical results reveal that access and usage of farm tools (e.g., tractors), profits, access and usage of irrigation facilities, doing agro-processing, land ownership, access to agricultural credits, membership in farmers' cooperatives and organizations, access to agricultural extension services, use of information source channels (e.g., radio, TV, and the internet), and distance to the nearest market are positively and statistically significantly explaining youth intensity of participation in agricultural activities.

Furthermore, general education and off-farm income are negatively and statistically significantly influencing youth intensity of engagement in agriculture. As youth get more education, it reduces the propensity of full-time involvement in agriculture. Youth with high education don't prefer developing careers in agricultural activities.

We employed a series of robust checks for the ordered logit model assumptions to make sure that regression results are consistent and unbiased.

The second paper in this chapter is entitled *"Youth Higher Intensity, Higher Gains? Empirical Evidence from Crop Farming in Tanzania.*" Extant initiatives and studies about youth involvement in agriculture focus on issues such as determinants, challenges faced by youth, opportunities in the sector, willingness to participate, attitudes and perceptions, and cognitive development towards decision-making and choosing a career in agriculture rather than the farm and economic performance of youth involved in agriculture.

To this end, there is scant evidence to verify whether youth intensity of participation in agriculture significantly improves farm performance. To embark on this gap, this paper investigates the impact of youths' intense engagement in agriculture on maize yields, net returns, and returns on investment (ROI). We adopted a doubly robust IPWRA estimator backed by PSM and ESR models. We used the nationally representative cross-section data of 3399 youths' maize farmers in Tanzania.

The empirical results revealed the factors that influenced youths' participation in agriculture. The results showed that factors such as gender (male), no formal education, household size, agricultural credit, membership in a farmers' cooperative, distance to the nearest market, access to irrigation facilities, and experience of past droughts are positive and statistically significant associated with youths' intensity of participation in the sector. In contrast, general education, off-farm income, and living in tropical cool, and semiarid areas are negatively and statistically significantly reducing the propensity to intensively engage in agriculture.

The results of the ATT coefficients depicted that youths' intensity of participation in agriculture increased all outcome variables while adopters outweighed their counterparts. For instance, the ATT of the intensity of participation on maize yields is 2.31% (but not statistically significant), for net returns is 4.07%, and for ROI is 9.5%. The positive impacts of the intensity of involvement on net returns and ROI are triggered by cost effects. Additionally, the complementary models of PSM and ESR results largely concur with the IPWRA results that the intensity of participation in agriculture significantly contributes to improvements in crop farming performance.

5.3. Main findings of Chapter 4

Chapter 4 includes one research paper entitled *"Impact analysis of agricultural finance on crop productivity among smallholder farmers in Tanzania."* This paper investigates the crucial role of agricultural finance on farm productivity for resources-constrained farmers using data gathered from a farm-based household survey in the project namely ''Integrated Project to Increase Agriculture Productivity in the Breadbasket Area of Southern Highlands of Tanzania" for the 2017-2018 farming season. The agricultural finance is proxied by agricultural credit for farmers who were able to obtain it.

Prior literature has examined the impacts of credit access on small and family farms in other places (Acclassato et al., 2021; Agbodji & Johnson, 2019; Assouto et al., 2023; Tripathi, 2017). However, the extant literature is silent on the impacts of agricultural finance on constrained Tanzanian smallholder household farmers.

It is evident that developing countries have inadequate agricultural finance, causing credit access constraints for smallholder household farmers. Revealing the effects of credit access on crop productivity in Tanzania remains weak. It is not clear whether agricultural finance augments crop productivity for smallholder farm households.

In this context, the study investigates the impact of credit access on crop productivity in Tanzania, one of the developing countries with weak agricultural finance and great credit constraints. The results have remained the same after surviving a series of tests as a robustness check.

Interestingly, farmers without credit counterfactual would increase their productivity by 15.09% if it is assumed there are no credit constraints.

Additionally, the paper investigates challenges facing financial markets that lead to credit rejection, and some farmers never seek agricultural credit to invest in agriculture. The critical challenges reported include lack of collateral and improper documents from the supply side. Further, risks associated with credit, lack of knowledge of how to get credit, too high interest rates, the perception that it is very difficult to get credit from financial entities, and financial institutions not being available near farmers are challenges from the demand side.

The paper reports the determinants of credit access, which include the cultivated area, use of herbicides and inorganic fertilizers, access to TV or radio programs related to agricultural practices, access to irrigation facilities, distance to farm, and access to the market. The same covariates play a role in crop productivity augmentation.

The findings have important policy implications in favour of smallholders' credit access. Reliable credit access by small-scale farmers has long impacts on food security and poverty reduction through crop productivity augmentation.

5.4. Contributions and Implications

This thesis contributes to the literature in several ways, as it consists of three important themes that are related to the transformation of African agriculture and attaining some SDGs. Overall, by using utility theory and production function in Chapter 2, this thesis adds to the literature useful insights that smallholder farmers can improve their crops productivity and boost their income when they adopt CSA in climatic-induced shocks.

Consistent with the extant empirical literature on the impact of CSA adoption on farm productivity and income, we contribute to the growing literature on the determinants of CSA usage and impacts of CSA on harvest and income (Akter et al., 2022; Amadu et al., 2020).

In detail, Chapter 2 adds to the current research on the impact of CSA technologies adoption by smallholder farmers. The chapter details the determinants of CSA usage. The determinants are subjective, meaning that they are different from one scenario to another (Mwongera et al., 2017). Also, the CSA adoption impacts and the extent of the effects on farm levels are distinct from one place to another (Coderoni & Pagliacci, 2023).

Therefore, the chapter contributes by advancing the literature on the determinants of CSA adoption among smallholder farmers in the Tanzanian context. In particular, the paper is relevant for informing stakeholders when setting targets and designing effective promotion of CSA adoption pathways in the face of climate change variability (Hellin & Fisher, 2018; Khatri-chhetri et al., 2016).

Further, the chapter contributes to the improvement of food security and poverty reduction. There is a clear linkage between CSA adoption and crop production and income improvement for the adopters. The resource-poor community boosts productivity and augments income, which advances SDGs of increasing crop production and alleviating poverty in a given adverse climatic variation (Mwalupaso et al., 2020).

Finally, chapter 2 contributes to the formulation of CSA adoption policy support measures. The analysis on crop specifics confirms the importance of feasible policy support to improve production for specific crops and smallholder farmers. The crops requirements and environment for farmers vary. They require context-specific solutions, which are flexible, supportive policy, and green finance available to them for sustainable farming (Abegunde et al., 2019; Lipper et al., 2014). The findings propose actionable policies such as agricultural education and farm-based training through farmer's cooperation and organization are crucial to scale up awareness and adoption of the appropriate CSA technologies to integrate into farming. Provision of extension services through agricultural officers can be an effective way to promote CSA adoption and augment both crops and income.

Chapter 3 introduces useful insights that youths' perceptions towards agricultural-related activities are driven by some extant stimuli or factors or youth backgrounds. If the extant stimuli or factors favour positive youth perception about agriculture, youth tend to engage and vice versa is true.

The contribution of this chapter is threefold; first, the paper contributes to the policy area as it examines the factors relevant for policy formulation. The factors examined may nurture positive or negative youths' perceptions about youth intensity of participation in agriculture. Policies should be relevant and flexibly change youth perceptions while stimulating youth's interest in involving them in agriculture. Relevant policies are important for institutions frameworks and infrastructure changes for the emancipation of youth economically through agriculture. The contribution is relevant due to the fact that most developing countries have policies, institutions, and infrastructures that are not well structured to motivate the youth high buy-in in agriculture (Heifer International, 2021).

Second, academically the paper adds value to the literature by employing the ordered logit model that enabled us to model the ordinal nature of the response variable ("not," "part-time," or "full-time") of youth intensity of participation in agriculture. Youth dynamics involvement in agriculture is a function of many interacting factors such as socio-economic, cultural, institutions, youth' demography, and environmental. It is non-superfluous for policies to account for youth heterogeneity requirements to offer effective solutions and supports in promoting effective youth engagement in agriculture (URT, 2022a).

Third, the paper provides insights to stakeholders that unlock potential embedded in agriculture for youth. Understanding factors affecting and influencing youth is crucial to induce full participation in agriculture. The paper is relevant to increasing limited awareness on factors that influence youth participation in agricultural opportunities (URT, 2022a). The contribution on awareness about problems, challenges, and drivers that influence full participation is relevant, to be able to augment agri-food production to feed the projected population of 53.9 in 2015 to 186.9 million Tanzanians within 2065. The insights are useful to be able to employ the projected number of youths rising from 17.8 to 62.3 million in the same year (Shayo, 2020). Winning youth buy-in in agriculture is projected to augment crop productivity and income as well as job creation. Eventually, it improves food security and reduces poverty (currently, 28% of Tanzanians are living in poverty). Attaining these important goals is in the light of SDGs attainment, as it is in many developing countries (Akrong & Hundie, 2022).

Furthermore, the second paper of this chapter has policy, academic, and practical implications. First, our findings of positive and negative factors significantly influence youths' levels of participation in agriculture. Also, the positive impact of the intense involvement in agriculture on maize yields, net returns, and ROI highlights important insights to stakeholders that the policy measures promoting youth higher-intensity involvement in agricultural activities are crucial. The government should ensure strategic integration of youth in the sector while minding the cost of production.

Second, the novelty of the study is meant to contribute to literature, as there are scant studies on the impact of youth on net returns and ROI. These findings can serve as references in the subsequent studies in the area.

Third, to the elderly and youths, our findings reveal the potential of agriculture on the returns on investment in the sector. Elders have evidence that there is a payoff from investment in agriculture. For youths, intensity of participation has meaningful implications for crop farming rather than partial participation, which is associated with more expenses in crop farming. It results in good farm management and high profits at relatively low costs.

Chapter 4 contributes to a growing literature on agricultural finance. The chapter consists of a paper that explores the reasons why there are credit rejection in reflection to credit rationing theory (Stiglitz & Weiss, 1981). The chapter add knowledge to the extant literature in other places that farmers given the risks associated with agriculture, some of small-scale farmers face credit constrains or rejection given the asymmetric information in the financial markets (Mukasa et al., 2017; Ali et al., 2014; Asante-addo et al., 2016; Balana et al., 2022; Bonnke et al., 2022; Guirkinger & Boucher, 2008; Hu et al., 2019).

Also, the chapter examines the determinants of credit access and covariates that hold a significant propensity for crop productivity. The study controlled the confounding or covariates using the ESR model and robustness check. The results remained pronounced that credit beneficiaries harvested more than non-beneficiaries. Surprisingly, credit-constrained smallholder farmers would significantly improve their crop harvests by 15.09% if they were unconstrained.

The contribution of chapter 4 in the extant literature and policy realms is as follows. First, the chapter contributes to advancing the literature on what really determines access to agricultural finance, particularly in the Tanzanian context. The paper provides useful insights to stakeholders when designing and planning for interventions to support small-scale farmers financially. This is relevant to boosting crop productivity and income, especially for resource-poor households in the exacerbating impact of climatic conditions (Abedifar et al., 2024).

Second, the paper contributes to improving food security and reducing poverty through the linkage of agricultural finance and augmentation of crop production in scarce resources and climatic stress. This is relevant since credit or loans improve important farm inputs and CSA usage and capacity building in unfavourable climatic conditions (Reyes et al., 2012; Arce & Arias, 2015; Girma, 2022; Jena et al., 2023; Teklewold et al., 2013). The resource-poor community boosts productivity and eventually augments income which advances SDGs such as ending hunger and poverty.

Finally, the paper contributes to the formulation of agricultural financing policy support measures. Precaution is required, bearing in mind that barriers vary among household farmers and locations. To meet their thirst for credit or loans, they require context-specific financing strategies and flexibility (Asante-addo et al., 2016; Nakano & Magezi, 2020; Salima et al., 2023).

5.5. Limitations and ventures for future research

This thesis uses cross-sectional data to investigate the determinants and impacts of CSA on farm-level productivity and income, youth involvement in agriculture, and agricultural finance in Tanzania. Some information was observed during the survey, other information and measurements were provided by farmers, which might carry potential measurement errors (e.g., self-reported yields). There might be incorrect recordings of some measurements. However, the findings in this thesis are not invalidated.

Future research directions could focus on revealing more determinants and impacts of CSA adoption by micro, medium, and macro farmers in extreme, moderate, and low climatic change impacts. Youth dynamics in agriculture and agricultural finance use can be investigated using cross-country data. Panel or time series data can capture the time-variant effects. Youth are dynamic and active individuals. They are shaped by institutional transformation. We suggest a study on how politics will influence youth buy-in in agricultural activities. Further, another analysis would involve a closer examination of the synergy and trade-off between increasing production and protecting the environment using cross-country perspective.

References

Abdulai, A. N. (2016). Impact of conservation agriculture technology on household welfare in Zambia. *Agricultural Economics (United Kingdom)*, *47*(6), 729–741. https://doi.org/10.1111/agec.12269

Abedifar, P., Kashizadeh, S. J., & Ongena, S. (2024). Flood, farms and credit: The role of branch banking in the era of climate change. *Journal of Corporate Finance*, *85*(January), 102544. https://doi.org/10.1016/j.jcorpfin.2024.102544

Abegunde, V. O., Sibanda, M., & Obi, A. (2019). *Determinants of the Adoption of Climate-Smart Agricultural Practices by Small-Scale Farming Households in King Cetshwayo District Municipality , South Africa*.

Acclassato, D., Goudjo, G. G., & Senou, M. M. (2021). Access to finance and difference in family farm productivity in Benin: Evidence from small farms. *Scientific African*, *13*, e00940. https://doi.org/10.1016/j.sciaf.2021.e00940

Adamon N. Mukasa, Anthony M. Simpasa, and A. O. S. (2017). *Credit constraints and farm productivity: Micro-level evidence from smallholder farmers in Ethiopia. Working Paper Series No. 247. African Development Bank Group* (Issue 247, pp. 1–40).

Adeyanju, D., Mburu, J., & Mignouna, D. (2021). *Youth Agricultural Entrepreneurship : Assessing the Impact of Agricultural Training Programmes on Performance*. 1–11.

African Development Bank (AfDB). (2016). *Jobs for Youth in Africa. Retrieved from. htt ps://www.afdb.org/fileadmin/uploads/afdb/Images/high_5s/Job_youth_Africa _Job_youth_Africa.pdf.* (pp. 1–2).

African Union. (2006). *African Youth Charter. https://au.int/sites/default/files/treaties/ 7789-treaty-0033_-_african_youth_charter_e.pdf.* (p. 22).

Agbodji, A. E., & Johnson, A. A. (2019). Agricultural Credit and Its Impact on the Productivity of Certain Cereals in Togo Agricultural Credit and Its Impact on the Productivity of Certain Cereals in Togo. *Emerging Markets Finance and Trade*, *0*(0), 1–17. https://doi.org/10.1080/1540496X.2019.1602038

Akrong, R., & Hundie, B. (2022). Heliyon Economic analysis of youth participation in agripreneurship in Benin. *Heliyon*, *8*(December 2021), e08738. https://doi.org/10.1016/j.heliyon.2022.e08738

Akter, A., Geng, X., Endelani, G., Lu, H., Hoque, F., Kiraru, M., & Abbas, Q. (2022). Climate Risk Management Income and yield effects of climate-smart agriculture (CSA) adoption in flood prone areas of Bangladesh : Farm level evidence. *Climate Risk Management*, *37*, 100455. https://doi.org/10.1016/j.crm.2022.100455

Albert, A., Hepelwa, A., Yami, M., & Manyong, V. (2020). *Assessment of Factors Influencing Youth Involvement in Horticulture Agribusiness in Tanzania : A Case Study of Njombe Region*.

Ali, D. A., Deininger, K., & Duponchel, M. (2014). Credit Constraints and Agricultural Productivity : Evidence from rural Rwanda. *The Journal OfDevelopment Studies*, *50*(5), 649–665. https://doi.org/10.1080/00220388.2014.887687

Allen, J., Pascual, K. S., Romasanta, R. R., Trinh, M. Van, Thach, T. Van, Hung, N. Van, & Sander, B. O. (2020). *Rice straw management effects on greenhouse gas emissions and mitigation options. In: Sustainable rice straw management. Springer, Cham, pp 145–159* (pp. 145–159). https://doi.org/10.1007/978-3-030-32373-8

Alvaro Reyes, Robert Lensink , Arie Kuyvenhoven, and H. M. (2012). *Impact of Access to Credit On Farm Productivity of Fruit and Vegetable Growers in Chile, Conference papers., https://researchgate.net/publication/254387617*. 1–32.

Amadu, F. O., Mcnamara, P. E., & Miller, D. C. (2020). Understanding the adoption of climate-smart agriculture : A farm-level typology with empirical evidence from southern Malawi. *World Development*, *126*, 104692. https://doi.org/10.1016/j.worlddev.2019.104692

Amadu, F. O., McNamara, P. E., & Miller, D. C. (2020). Yield effects of climate-smart agriculture aid investment in southern Malawi. *Food Policy*, *92*(January 2019), 101869. https://doi.org/10.1016/j.foodpol.2020.101869

Arce, C., & Arias, D. (2015). *Paraguay Agricultural Sector Risk Assessment*. *93943*.

Asante-addo, C., Mockshell, J., Zeller, M., Berlin, H., & Egyir, I. S. (2016). *Agricultural credit provision : what really determines farmers ' participation and credit rationing ? 77*(2), 239–256. https://doi.org/10.1108/AFR-02-2016-0010

Assouto, A. B., Houngbeme, D. J., Assouto, A. B., & Houngbeme, D. J. (2023). Cogent Economics & Finance Access to credit and agricultural productivity : Evidence from maize producers in Benin Access to credit and agricultural productivity : Evidence from maize producers in Benin. *Cogent Economics & Finance*, *11*(1). https://doi.org/10.1080/23322039.2023.2196856

August, M. M. (2020). *Youths' aspirations and perceptions towards agricultural participation: a case of two Free State regions (Doctoral dissertation, University of the Free State).*

Autio, A., Johansson, T., Motaroki, L., Minoia, P., & Pellikka, P. (2021). Constraints for adopting climate-smart agricultural practices among smallholder farmers in Southeast Kenya. *Agricultural Systems*, *194*(January), 103284. https://doi.org/10.1016/j.agsy.2021.103284

Balana, B. B., Mekonnen, D., Haile, B., Hagos, F., Yimam, S., & Ringler, C. (2022). Demand and supply constraints of credit in smallholder farming : Evidence from Ethiopia and Tanzania. *World Development*, *159*, 106033. https://doi.org/10.1016/j.worlddev.2022.106033

Balew, S., Agwata, J., & Anyango, S. (2014). *Determinants of Adoption Choices of Climate Change Adaptation Strategies in Crop Production by Small Scale Farmers in Some Regions of Central Ethiopia*. *4*(4).

Baloyii, R., Wale, E., & Chipfupa, U. (2023). Rural youth interest in economic activities along the agricultural value chain: empirical evidence from Kwazulu-Natal (South Africa) and implications. *International Food and Agribusiness Management Review*, *26*(1), 49–65. https://doi.org/10.22434/IFAMR2021.0036

Belay, M., Bekele, G., & Ibrahim, M. (2022). Heliyon Measuring the poverty reduction effects of adopting agricultural technologies in rural Ethiopia : fi ndings from an endogenous switching regression approach. *Heliyon*, *8*(November 2021), e09495. https://doi.org/10.1016/j.heliyon.2022.e09495

Bergen, M. Van, Steeman, M., Reindorp, M., & Gelsomino, L. (2019). Journal of Purchasing and Supply Management Supply chain finance schemes in the procurement of agricultural products. *Journal of Purchasing and Supply Management*, *25*(2), 172–184. https://doi.org/10.1016/j.pursup.2018.08.003

Berger, T., Troost, C., Wossen, T., Latynskiy, E., Tesfaye, K., & Gbegbelegbe, S. (2017). Can smallholder farmers adapt to climate variability, and how effective are policy interventions? Agent-based simulation results for Ethiopia. *Agricultural Economics (United Kingdom)*, *48*(6), 693–706. https://doi.org/10.1111/agec.12367

Betcherman, G. (2018). *Jobs for Africa ' s expanding youth cohort : a stocktaking of employment prospects and policy interventions*. https://doi.org/10.1186/s40176-018-0121-y

Bhatnagar, S., Chaudhary, R., Sharma, S., Janjhua, Y., Thakur, P., Sharma, P., & Keprate, A. (2024). Environmental and Sustainability Indicators Exploring the dynamics of climate-smart agricultural practices for sustainable resilience in a changing climate. *Environmental and Sustainability Indicators*, *24*(May), 100535. https://doi.org/10.1016/j.indic.2024.100535

Bierbaum, R. M., & Zoellick, R. B. (2009). Development and climate change. In *Science* (Vol. 326, Issue 5954). https://doi.org/10.1126/science.1183876

Blattman, C., & Jeannie Annan. (2011). *Evidence from Randomized Evaluations of Peacebuilding in Reintegrating and Employing High Risk Youth in Liberia : Lessons from a randomized evaluation of a Landmine Action agricultural training program for ex-combatants Table of Contents*.

Boansi, D., Gyasi, M., Nuamah, S., Tham-Agyekum, E. K., Ankuyi, F., Frimpong, R., Gbafah, A., & Gyan, C. B. (2024). Impact of agricultural credit on productivity, cost and returns from cocoa production in Ghana. *Cogent Economics and Finance*, *12*(1). https://doi.org/10.1080/23322039.2024.2402035

Bongole, A. J. (2022). *AJER, Volume 10 (2), March 2022, A.J., Bongole Welfare Effects of Farming Household' Usage of Combination of Climate Smart Agriculture Practises in the Southern Highlands of Tanzania. Abiud J. Bongole †* (Vol. 10, Issue March).

Bongole, A. J., Hella, J., Kikuu, C., Resource, N., & Kikuu, C. (2020). *Usage of Climate Smart Agriculture Practices: An Analysis of Farm Households' Decisions in Southern Highlands of Tanzania 1*. *19*(2), 238–255.

Bongole, A. J., Hella, J. P., & Bengesi, K. M. K. (2022). Combining Climate Smart Agriculture Practises Pays Off: Evidence on Food Security From Southern Highland Zone of Tanzania. *Frontiers in Sustainable Food Systems*, *6*(April), 1–17. https://doi.org/10.3389/fsufs.2022.541798

Bonnke, S. M., Martin, P., Nguezet, D., Nyamugira, A., Jean-jacques, M. S., & Manyong, V. (2022). *Farmers ' credit access in the Democratic Republic of Congo : Empirical evidence from youth tomato farmers in Ruzizi plain in South Kivu Farmers ' credit access in the Democratic Republic of Congo : Empirical evidence from youth tomato farmers in Ruzizi p*. *May*. https://doi.org/10.1080/23322039.2022.2071386

Boye, M., Ghafoor, A., Wudil, A. H., Usman, M., Prus, P., Feh, A., & Sass, R. (2024). *Youth Engagement in Agribusiness : Perception , Constraints , and Skill Training Interventions in Africa : A Systematic Review*.

Chakrabarti, S. (2018). *"The Youth Advantage: Engaging young people in green growth." IFAD Advantage Series. Rome: IFAD.* (p. 33).

Coderoni, S., & Pagliacci, F. (2023). The impact of climate change on land productivity. A micro-level assessment for Italian farms. *Agricultural Systems*, *205*(October 2022), 103565. https://doi.org/10.1016/j.agsy.2022.103565

Craparo, A. C. W., Van Asten, P. J. A., Läderach, P., Jassogne, L. T. P., & Grab, S. W. (2015). Coffea arabica yields decline in Tanzania due to climate change: Global implications.

Agricultural and Forest Meteorology, *207*, 1–10. https://doi.org/10.1016/j.agrformet.2015.03.005

Daum, T., Ygu, P., Adegbola, C., Daudu, C., Issa, F., Kamau, G., Oumar, A., Mose, L., Ndirpaya, Y., Fatunbi, O., Zossou, R., Kirui, O., & Birner, R. (2022). *Mechanization , digitalization , and rural youth - Stakeholder perceptions on three mega-topics for agricultural transformation in four African countries*. *32*. https://doi.org/10.1016/j.gfs.2022.100616

Dercon, S., & Christiaensen, L. (2011). Consumption risk, technology adoption and poverty traps: Evidence from Ethiopia. *Journal of Development Economics*, *96*(2), 159–173. https://doi.org/10.1016/j.jdeveco.2010.08.003

Elizabeth, H., Mary, S., Whitfield, S., Gaworek-michalczenia, M. F., Walker, J., Joseph, G., & Mziray, S. (2021). Innovation systems and affordances in climate smart agriculture. *Journal of Rural Studies*, *87*(January), 199–212. https://doi.org/10.1016/j.jrurstud.2021.09.001

Ellinger, P. N., & Penson, J. B. (2014). Agricultural Finance. *Encyclopedia of Agriculture and Food Systems*, *1*, 92–104. https://doi.org/10.1016/B978-0-444-52512-3.00109-1

FAO. (2010). The State of Food Insecurity in the World Addressing food insecurity in protracted crises 2010 Key messages. In *Notes*.

FAO. (2013). *FAO. 2013. Climate smart agriculture sourcebook. Rome: Food and Agriculture Organisation.* (pp. 1–263). https://doi.org/10.3726/b11522

FAO. (2014). *FAO Regional Conference for Africa: African Youth in Agribusiness and Rural Development* (Issue January, p. 11). Tunis, Tunisia, 24-28 March 2014.

FAO. (2015). *The economic lives of smallholder farmers* (p. 48).

FAO. (2017). *The future of food and agriculture Trends and challenges* (p. 180).

FAO. (2018). Global Forum on Food Security and Nutrition Youth employment in agriculture as a solid solution to ending hunger and poverty in Africa. In *Global Forum on Food Security and Nutrition* (pp. 1–9).

Feng, X., Sun, T., Guo, J., Cai, H., Qian, C., Hao, Y., Yu, Y., Deng, A., Song, Z., & Zhang, W. (2023). Climate-smart agriculture practice promotes sustainable maize production in northeastern China: Higher grain yield while less carbon footprint. *Field Crops Research*, *302*(April), 109108. https://doi.org/10.1016/j.fcr.2023.109108

Filmer & Fox. (2014). *Youth Employment in Sub-Saharan Africa. Africa Development Series. Washington, DC: World Bank. doi:10.1596/978-1-4648-0107-5. License: Creative Commons Attribution CC BY 3.0* (p. 283).

Geza, W., Ngidi, M., Ojo, T., Adetoro, A. A., Slotow, R., & Mabhaudhi, T. (2021). Youth participation in agriculture: A scoping review. *Sustainability (Switzerland)*, *13*(16), 1–15. https://doi.org/10.3390/su13169120

Geza, W., Ngidi, M. S. C., Slotow, R., & Mabhaudhi, T. (2022). The Dynamics of Youth Employment and Empowerment in Agriculture and Rural Development in South Africa: A Scoping Review. *Sustainability (Switzerland)*, *14*(9). https://doi.org/10.3390/su14095041

Gikonyo, N. W., Busienei, J. R., Gathiaka, J. K., & Karuku, G. N. (2022). Analysis of Household Savings and Adoption of Climate Smart Agricultural Technologies. Evidence from Smallholder Farmers in Nyando Basin, Kenya. *HELIYON*, e09692. https://doi.org/10.1016/j.heliyon.2022.e09692

Girma, Y. (2022). Credit access and agricultural technology adoption nexus in Ethiopia : A systematic review and meta-analysis. *Journal of Agriculture and Food Research*, *10*(March), 100362. https://doi.org/10.1016/j.jafr.2022.100362

Guirkinger, C., & Boucher, S. R. (2008). Credit constraints and productivity in Peruvian agriculture. *Agricultural Economics*, *39*(3), 295–308. https://doi.org/10.1111/j.1574-0862.2008.00334.x

Guo, G., Wen, Q., & Zhu, J. (2015). *The Impact of Aging Agricultural Labor Population on Farmland Output : From the Perspective of Farmer Preferences*. *2015*, 7. https://doi.org/http://dx.doi.org/10.1155/2015/730618

Habtewold, T. M. (2021). Impact of climate-smart agricultural technology on multidimensional poverty in rural Ethiopia. *Journal of Integrative Agriculture*, *20*(4), 1021–1041. https://doi.org/10.1016/S2095-3119(21)63637-7

Haji Athumani Msangi, Betty Waized, Daniel Wilson Ndyetabula, V. M. M. (2024). Heliyon Promoting youth engagement in agriculture through land titling programs : Evidence from Tanzania. *Heliyon*, *10*(7), e29074. https://doi.org/10.1016/j.heliyon.2024.e29074

Heifer International. (2021). *The future of Africa's agri- culture - an assessment of the role of youth and technology. https://media.heifer.org/About_Us/ Africa-Agriculture-Tech-2021.pdf*.

Hellin, J., & Fisher, E. (2018). Development in Practice Building pathways out of poverty through climate smart agriculture and effective targeting agriculture and e ff ective targeting. *Development in Practice*, *28*(7), 1–6. https://doi.org/10.1080/09614524.2018.1492516

Henning, J. I. F., Matthews, N., August, M., & Madende, P. (2022). *Youths ' Perceptions and Aspiration towards Participating in the Agricultural Sector : A South African Case Study*.

Hu, L., Lopez, R. A., & Zeng, Y. (2019). The impact of credit constraints on the performance of Chinese agricultural wholesalers. *Applied Economics*, *0*(0), 1–12. https://doi.org/10.1080/00036846.2019.1584385

Hu, Y., Liu, C., & Peng, J. (2021). Financial inclusion and agricultural total factor productivity growth in China. *Economic Modelling*, *96*(November 2020), 68–82. https://doi.org/10.1016/j.econmod.2020.12.021

Huang, H., von Lampe, M., & van Tongeren, F. (2011). Climate change and trade in agriculture. *Food Policy*, *36*(SUPPL. 1), S9–S13. https://doi.org/10.1016/j.foodpol.2010.10.008

International Fund for Agricultural Development (IFAD). (2019). *The Narrative on Rural Youth and Economic Opportunities in Africa: Facts, Myths and Gaps. https://www.i fad.org/documents/38714170/41187395/21_MabisoþandþBenfica_2019þRDRþ BACKGROUNDþPAPER.pdf/f741a15a-49c1-93ae-5155-5b0ef7bdf733.*

Islam, T., & Nursey-bray, M. (2017). Adaptation to climate change in agriculture in Bangladesh : The role of formal institutions. *Journal of Environmental Management*, *200*, 347–358. https://doi.org/10.1016/j.jenvman.2017.05.092

Jagustovi, R., Papachristos, G., Zougmor, R. B., Kotir, J. H., Kessler, A., & Ou, M. (2021). *Better before worse trajectories in food systems ? An investigation of synergies and trade-offs through climate-smart agriculture and system dynamics*. *190*(April). https://doi.org/10.1016/j.agsy.2021.103131

Janzen, T. (2014). *Environmental. Legal news rooms. https://www.lexisnexis.com/legalnewsroom/environ mental/b/environmentalregulation/posts/the-chal lenges-facing-liberian-agriculture*. 2014.

Jena, P. R., Tanti, P. C., & Maharjan, K. L. (2023). Determinants of adoption of climate resilient

practices and their impact on yield and household income. *Journal of Agriculture and Food Research*, *14*(June), 100659. https://doi.org/10.1016/j.jafr.2023.100659
Ji-kun, H., & Yang-jie, W. (2014). Financing Sustainable Agriculture Under Climate Change. *Journal of Integrative Agriculture*, *13*(4), 698–712. https://doi.org/10.1016/S2095-3119(13)60698-X
Jones, K., Nowak, A., Berglund, E., Grinnell, W., Temu, E., Paul, B., Renwick, L. L. R., Steward, P., Rosenstock, T. S., & Kimaro, A. A. (2023). Evidence supports the potential for climate-smart agriculture in Tanzania. *Global Food Security*, *36*(December 2021), 100666. https://doi.org/10.1016/j.gfs.2022.100666
Kafle, K., Paliwal, N., & Benfica, R. (2019a). Who Works in Agriculture? Exploring the Dynamics of Youth Involvement in the Agri-Food Systems of Tanzania and Malawi. In *SSRN Electronic Journal* (Issue June). https://doi.org/10.2139/ssrn.3366984
Kafle, K., Paliwal, N., & Benfica, R. (2019b). Who Works in Agriculture? Exploring the Dynamics of Youth Involvement in the Agri-Food Systems of Tanzania and Malawi. In *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3366984
Kaki, R. S., Mignouna, D. B., Aoudji, A. K. N., Adéoti, R., Kaki, R. S., Mignouna, D. B., Aoudji, A. K. N., Adéoti, R., & Kaki, R. S. (2022). *Entrepreneurial Intention among Undergraduate Agricultural Students in the Republic of Benin Entrepreneurial Intention among Undergraduate Agricultural Students in the Republic of Benin*. https://doi.org/10.1080/15228916.2022.2031584
Kalya Dennis Maritim. (2020). *Assessment of Factors Influencing Youth Participation in Agri-Business in Kericho County, Kenya (Doctoral dissertation, KeMU).*
Karen Brooks, Sergiy Zorya, Amy Gautam, & Goyal, A. (2013). *Agriculture as a sector of opportunity for young people in Africa (pp. 64–73). World Bank Policy Research Working Paper.*
Khatri-chhetri, A., Aggarwal, P. K., Joshi, P. K., & Vyas, S. (2016). Farmers ' prioritization of climate-smart agriculture (CSA) technologies. *AGSY*. https://doi.org/10.1016/j.agsy.2016.10.005
Khatri-Chhetri, A., Aggarwal, P. K., Joshi, P. K., & Vyas, S. (2017). Farmers' prioritization of climate-smart agriculture (CSA) technologies. *Agricultural Systems*, *151*, 184–191. https://doi.org/10.1016/j.agsy.2016.10.005
Kifle, T., Yayeh, D., & Mulugeta, M. (2022). Factors influencing farmers adoption of climate smart agriculture to respond climate variability in Siyadebrina Wayu District , Central highland of Ethiopia. *Climate Services*, *26*(December 2020), 100290. https://doi.org/10.1016/j.cliser.2022.100290
Kimaro, A. A., Mpanda, M., Rioux, J., Aynekulu, E., Shaba, S., Thiong, M., Abwanda, S., Shepherd, K., Neufeldt, H., & Rosenstock, T. S. (2015). Is conservation agriculture ' climate-smart ' for maize farmers in the highlands of Tanzania ? *Nutrient Cycling in Agroecosystems*. https://doi.org/10.1007/s10705-015-9711-8
Kurgat, B. K., Lamanna, C., Kimaro, A., Namoi, N., Manda, L., & Rosenstock, T. S. (2020). *Adoption of Climate-Smart Agriculture Technologies in Tanzania*. *4*(May). https://doi.org/10.3389/fsufs.2020.00055
Kwaku, J., Tiah, J., & Kasim, R. (2017). Land Use Policy Dynamics of youth access to agricultural land under the customary tenure regime in the Techiman traditional area of Ghana. *Land Use Policy*, *60*, 254–266. https://doi.org/10.1016/j.landusepol.2016.10.040

Lindsjö, K., Djurfeldt, A. A., Isinika, A. C., & Msuya, E. (2020). Youths' participation in agricultural intensification in Tanzania. *AIMS Agriculture and Food*, *5*(4), 681–699. https://doi.org/10.3934/agrfood.2020.4.681

Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck, A., Neufeldt, H., Remington, T., … Torquebiau, E. F. (2014). Climate-smart agriculture for food security. *Nature Climate Change*, *4*(12), 1068–1072. https://doi.org/10.1038/nclimate2437

Losch, B. (2016). Structural transformation to boost youth labour demand in Sub-Saharan Africa : the role of agriculture, rural areas and territorial development. *Employment Working Paper ; No. 204 1999-2939*.

Lucy Karega Njeru. (2017). Youth in Agriculture ; Perceptions and Challenges for Enhanced Participation in Kajiado North Sub-County, Kenya. *Greener Journal of Agricultural Sciences*, *7*(8), 203–209. https://doi.org/10.15580/GJAS.2017.8.100117141

Magagula, B., & Tsvakirai, C. Z. (2019). Development in Practice Youth perceptions of agriculture : influence of cognitive processes on participation in agripreneurship. *Development in Practice*, *0*(0), 1–10. https://doi.org/10.1080/09614524.2019.1670138

Magagula, B., & Tsvakirai, C. Z. (2020). Development in Practice Youth perceptions of agriculture : influence of cognitive processes on participation in agripreneurship. *Development in Practice*, *30*(2), 234–243. https://doi.org/10.1080/09614524.2019.1670138

Maiga, E. W. H. (2016). Determinants of changes in youth and women agricultural labor participation in selected African countries. *Agricultural & Applied Economics Association Annual Meeting*, 1–18.

Maina, K. W., Ritho, C. N., Lukuyu, B. A., & Rao, E. J. O. (2020). Heliyon Socio-economic determinants and impact of adopting climate-smart Brachiaria grass among dairy farmers in Eastern and Western regions of Kenya. *Heliyon*, *6*(May), e04335. https://doi.org/10.1016/j.heliyon.2020.e04335

Martinson, A. T., Yuansheng, J., & Monica, O. A. (2019). Determinants of agriculture participation among tertiary institution youths in Ghana. *Journal of Agricultural Extension and Rural Development*, *11*(3), 56–66. https://doi.org/10.5897/JAERD2018.1011

Mcmullin, J. R. (2022). *Hustling , cycling , peacebuilding : Narrating postwar reintegration through livelihood in Liberia*. 67–90. https://doi.org/10.1017/S0260210521000255

Mengistu, M. (2017). Graduate Employability as a Function of Career Decision in the Amhara State TVET System. *Ethiopian Journal of Education and Sciences*, *13*(1), 1–21.

Miriti, G. M. (2020). An Exploration of Entrepreneurial Intentions among University Students in Kenya. *International Journal of Research and Innovation in Social Science (IJRISS)*, *IV*(Xii), 521–529.

Mittal, Surabhi, V. K. H. (2018). Climate Risk Management Mobile-based climate services impact on farmers risk management ability in India. *Climate Risk Management*, *22*(August), 42–51. https://doi.org/10.1016/j.crm.2018.08.003

Mittal, S., & Mehar, M. (2015). *Socio-economic Factors Affecting Adoption of Modern Information and Communication Technology by Farmers in India : Analysis Using Multivariate Probit Model*. *9711154443*, 1–14.

Morsy, H., & Mukasa, A. N. (2019). *Youth Jobs, Skill and Educational Mismatches in Africa, Working Paper Series N° 326, African Development Bank, Abidjan, Côte d'Ivoire.*

Mthi, S., Yawa, M., Tokozwayo, S., & Ikusika, O. O. (2021). *An Assessment of Youth Involvement in Agricultural Activities in Eastern Cape Province , South Africa*. 1034–1047. https://doi.org/10.4236/as.2021.1210066

Mugabe, P. A. (2020). Assessment of Information on Successful Climate-Smart Agricultural Practices/ Innovations in Tanzania. *Handbook of Climate Change Resilience, Volume 1-4*, *4*, 2721–2741. https://doi.org/10.1007/978-3-319-93336-8_180

Mukembo, S. C., Edwards, M. C., Ramsey, J. W., & Henneberry, S. R. (2014). *Attracting Youth to Agriculture : The Career Interests of Young Farmers Club Members in Uganda*. *55*(5), 155–172. https://doi.org/10.5032/jae.2014.05155

Murray, U., Gebremedhin, Z., Brychkova, G., & Spillane, C. (2016). *Smallholder Farmers and Climate Smart Agriculture : Technology and Constraints amongst Women Smallholders in Malawi*. https://doi.org/10.1177/0971852416640639

Muthomi, E. (2017). Challenges and opportunities for youth engaged in agribusiness in Kenya. *Journal of Culture, Society and Development*, *17*(1), 4–19.

Mwalupaso, G. E., Wang, S., Eshetie, A. M., & Tian, X. (2020). *Ameliorating Food and Nutrition Security in Farm Households : Does Informatization Matter ?* 1–20.

Mwongera, C., Shikuku, K. M., Twyman, J., Läderach, P., Ampaire, E., Van Asten, P., Twomlow, S., & Winowiecki, L. A. (2017). Climate smart agriculture rapid appraisal (CSA-RA): A tool for prioritizing context-specific climate smart agriculture technologies. *Agricultural Systems*, *151*, 192–203. https://doi.org/10.1016/j.agsy.2016.05.009

Nakano, Y., & Magezi, E. F. (2020). The impact of microcredit on agricultural technology adoption and productivity : Evidence from randomized control trial in Tanzania. *World Development*, *133*, 104997. https://doi.org/10.1016/j.worlddev.2020.104997

Newell, P., Taylor, O., Naess, L. O., Thompson, J., Mahmoud, H., Ndaki, P., Rurangwa, R., & Teshome, A. (2019). Climate Smart Agriculture? Governing the Sustainable Development Goals in Sub-Saharan Africa. *Frontiers in Sustainable Food Systems*, *3*(August), 1–15. https://doi.org/10.3389/fsufs.2019.00055

Ngaiwi, M. E., Molua, E. L., Sonwa, D. J., Meliko, M. O., Bomdzele, E. J., Ayuk, J. E., Castro-Nunez, A., & Latala, M. M. (2023). Do farmers' socioeconomic status determine the adoption of conservation agriculture? An empirical evidence from Eastern and Southern Regions of Cameroon. *Scientific African*, *19*. https://doi.org/10.1016/j.sciaf.2022.e01498

Nikam, V., Ashok, A., & Pal, S. (2022). Farmers' information needs, access and its impact: Evidence from different cotton producing regions in the Maharashtra state of India. *Agricultural Systems*, *196*(March 2021), 103317. https://doi.org/10.1016/j.agsy.2021.103317

Ninson, J., & Brobbey, M. K. (2023). "Review on engaging the youth in agribusiness", Cogent Social Sciences, 9:1, 2193480, DOI: 10.1080/23311886.2023.2193480. *Cogent Social Sciences*, *9*(1). https://doi.org/10.1080/23311886.2023.2193480

Noltze, M., Schwarze, S., & Qaim, M. (2013). Impacts of natural resource management technologies on agricultural yield and household income: The system of rice intensification in Timor Leste. *Ecological Economics*, *85*, 59–68. https://doi.org/10.1016/j.ecolecon.2012.10.009

Ntinyari, W., & Gweyi-onyango, J. P. (2021). *Greenhouse Gases Emissions in Agricultural Systems and Climate Change Effects in Sub- Saharan Africa*. 1081–1105.

Nyasimi, M., Kimeli, P., Sayula, G., Radeny, M., Kinyangi, J., & Mungai, C. (2017). Adoption and dissemination pathways for climate-smart agriculture technologies and practices for climate-resilient livelihoods in Lushoto, Northeast Tanzania. *Climate*, *5*(3), 1–22. https://doi.org/10.3390/cli5030063

Ogada, M. J., Radeny, M., Recha, J., & Dawit, S. (2021). Adoption of complementary climate - smart agricultural technologies : lessons from Lushoto in Tanzania. *Agriculture & Food Security*, 1–10. https://doi.org/10.1186/s40066-021-00321-w

Ojo, T. O., Kassem, H. S., Ismail, H., & Adebayo, D. S. (2023). Level of adoption of climate smart agriculture among smallholder rice farmers in Osun State: does financing matter? *Scientific African*, *21*(August), e01859. https://doi.org/10.1016/j.sciaf.2023.e01859

Osabohien, R., Wiredu, A. N., Matin, P., Nguezet, D., Mignouna, D. B., Abdoulaye, T., Manyong, V., Bamba, Z., & Awotide, B. A. (2021). *Youth Participation in Agriculture and Poverty Reduction in Nigeria*. 1–19.

Ramgopaul Roop, Miles Weaver, A. P. F. & M. M. (2023). Innovative Approaches in Smallholder Farming Systems to Implement the Sustainable Development Goals. In *SDGs in the Americas and Caribbean Region* (pp. 1–28).

Rodríguez-Barillas, M., Klerkx, L., & Poortvliet, P. M. (2024). What determines the acceptance of Climate Smart Technologies? The influence of farmers' behavioral drivers in connection with the policy environment. *Agricultural Systems*, *213*(November 2023), 103803. https://doi.org/10.1016/j.agsy.2023.103803

Rowhani, P., Lobell, D. B., Linderman, M., & Ramankutty, N. (2011). Climate variability and crop production in Tanzania. *Agricultural and Forest Meteorology*, *151*(4), 449–460. https://doi.org/10.1016/j.agrformet.2010.12.002

Saj, S., Torquebiau, E., Hainzelin, E., Pages, J., & Maraux, F. (2017). Agriculture , Ecosystems and Environment The way forward : An agroecological perspective for Climate-Smart Agriculture. *Agriculture, Ecosystems and Environment*, *250*(July), 20–24. https://doi.org/10.1016/j.agee.2017.09.003

Salima, W., Manja, L. P., Chiwaula, L. S., & Chirwa, G. C. (2023). The impact of credit access on household food security in Malawi. *Journal of Agriculture and Food Research*, *11*(November 2022), 100490. https://doi.org/10.1016/j.jafr.2022.100490

Sanga, C., Kalungwizi, V. J. & Msuya, C. P. (2013). Building an agricultural extension services system supported by ICTs in Tanzania : Progress made , Challenges remain *International Journal of Education and Development Using Information and Communication Technology (IJEDICT)*, *9*(1), 80–99.

Scherr, S. J., Shames, S., & Friedman, R. (2012). *From climate-smart agriculture to climate-smart landscapes*. 1–15.

Shakoor, A., Shahbaz, M., Farooq, T. H., Sahar, N. E., Shahzad, S. M., Altaf, M. M., & Ashraf, M. (2021). A global meta-analysis of greenhouse gases emission and crop yield under no-tillage as compared to conventional tillage. *Science of the Total Environment*, *750*, 142299. https://doi.org/10.1016/j.scitotenv.2020.142299

Shayo, A. H. (2020). *The Role Of Education System In Preparing Youth For Agricultural Career Decisions And Aspirations: Exploring Ways To Attract More Youth To Engage In Agriculture And Agricultural Entrepreneurship In Tanzania. Dissertation submitted to the faculty of the Vi*.

Shemsanga, C., Omambia, A. N., & Gu, Y. (2010). The Cost of Climate Change in Tanzania: Impacts and Adaptations. *Journal of American ScienceJournal of American Science*, *6*(63),

182–196.
Stiglitz, J. E., & Weiss, A. (1981). Credit Rationing in Markets with Imperfect Information Joseph E . Stiglitz ; Andrew Weiss. *The American Economic Review*, *71*(3), 393–410.
Sumberg, J., Yeboah, T., Flynn, J., & Anyidoho, N. A. (2017). *Young people ' s perspectives on farming in Ghana : a Q study*. 151–161. https://doi.org/10.1007/s12571-016-0646-y
Tanti, P. C., Jena, P. R., Aryal, J. P., & Rahut, D. B. (2022). Role of institutional factors in climate-smart technology adoption in agriculture: Evidence from an Eastern Indian state. *Environmental Challenges*, *7*(February), 100498. https://doi.org/10.1016/j.envc.2022.100498
Taylor, M. (2017). Climate-smart agriculture : what is it good for ? *The Journal of Peasant Studies*, *0*(0), 1–19. https://doi.org/10.1080/03066150.2017.1312355
Teklewold, H., Adam, R. I., & Marenya, P. (2020). What explains the gender differences in the adoption of multiple maize varieties? Empirical evidence from Uganda and Tanzania. *World Development Perspectives*, *18*(July 2019), 100206. https://doi.org/10.1016/j.wdp.2020.100206
Teklewold, H., Kassie, M., & Shiferaw, B. (2013). Adoption of multiple sustainable agricultural practices in rural Ethiopia. *Journal of Agricultural Economics*, *64*(3), 597–623. https://doi.org/10.1111/1477-9552.12011
The Allience for a Green Revolution in Africa (AGRA). (2019). *Youth Strategy : Empowering youth for agricultural transformation. West End Towers, 4th Floor Kanjata Road, Muthangari Drive, Waiyaki Way P.O. Box 66773, Westlands 00800 Nairobi, Kenya* (pp. 1–12).
The United Republic of Tanzania (URT). (2013). *National agriculture policy, Dar es Salaam, October 2013*.
The United Republic of Tanzania (URT). (2025). *Long-term vision for a low emission development strategy*.
Tripathi, A. K. (2017). Credit for Agricultural Households in India: Growing Inequities. *Journal of Asian and African Studies*, *52*(6), 807–823. https://doi.org/10.1177/0021909615618983
UN. (2015). *Sustainable Development Goals, 11 August 2015, New York* (Issue August, p. 31).
UNEP. (2022). *Adapatation gap report 2022: Too little, too slow – Climate adaptation failure puts world at risk*. https://www.unep.org/adaptation-gap-report-2022
Unity, Chifupa & Aluwani, T. (2021). Youth ' s participation in agriculture : A fallacy or achievable possibility ? Evidence from rural South Africa. *South African Journal of Economic and Management Sciences*, *24*(1), a4004. https://doi.org/https://doi.org/10.4102/sajems.v24i1.4004
URT. (2007). *National Youth Development Policy* (pp. 1–33). Ministry of Labour, Employment and Youth Development.
URT. (2013). *National Agriculture Policy - 2013* (Issue October). MINISTRY OF AGRICULTURE FOOD SECURITY AND COOPERATIVES DAR.
URT. (2015). *Tanzania Climate Smart Agriculture Programme.* (pp. 1–82).
URT. (2016a). National Strategy for Youth Involvement in Agriculture. In *Ministry of Agriculture Livestock and Fisheries* (pp. 2016–2021).
URT. (2016b). *Prime Minister' S Office - United Republic of Tanzania World Food Program (WFP) Strategic Review 2016: Framework for Food and Nutrition Security in Tanzania Endorsed Strategic Review Report-November 2016 Technical Expert Donor/Funder* (Issue

113, p. 114).
URT. (2017). *Agricultural Sector Development Programme Phase II (ASDP II) November, 2017*.
URT. (2022a). *Building A Better Tomorrow: Youth Initiative For Agribusiness (BBT-YIA) 2022-2030* (pp. 1–62).
URT. (2022b). *Tanzania National Bureau of Statistics and President's Office – Finance and Planning, Office of the Chief Government Statistician, Zanzibar. The 2022 Population and Housing Census: Age and Sex Distribution Report, Key Findings, Tanzania, December 2022.* (pp. 1–23).
Verick, S. (2009). *Who Is Hit Hardest during a Financial Crisis ? The Vulnerability of Young Men and Women to Who Is Hit Hardest during a Financial Crisis ? The Vulnerability of Young Men and Women to Unemployment in an Economic Downturn*. *4359*.
Waithaka, M. M., Thornton, Æ. P. K., Shepherd, K. D., & Ndiwa, Æ. N. N. (2007). *Factors affecting the use of fertilizers and manure by smallholders : the case of Vihiga , western Kenya*. *78*, 211–224. https://doi.org/10.1007/s10705-006-9087-x
Williams, J., Daily, G., Noble, A., Matthews, N., Gordon, L., Wetterstrand, H., Declerck, F., Shah, M., Steduto, P., Fraiture, C. De, Hatibu, N., Unver, O., Bird, J., & Sibanda, L. (2016). *Sustainable intensification of agriculture for human prosperity and global sustainability*. https://doi.org/10.1007/s13280-016-0793-6
Winthrop et al. (2018). Tanzania Country Climate Change Risk Assessment Report. In *Irish Aid, Resilience and Economic Inclusion Team, Policy Unit February,*.
Wole-Alo I. Felicia, Falase O. Emmanuel, A. T. O. (2016). Assessing the future of agriculture in the hands of rural youth in oriade local government area of osun state, Nigeria. *International Journal of Agricultural Extension*, *4*(2), 105–110.
World Bank (WB). (2011). World development report 2011: Conflict, Security, and Development. *The World Bank, 1818 H Street NW, Washington, DC 20433, USA; Fax: 202-522-2422; e-Mail: Pubrights@worldbank.Org.*
Wuni, I. Y., Boafo, H., & Dinye, R. D. (2017). *Examining the Non-Participation of Some Youth in Agriculture in the Midst of Acute Unemployment in Ghana*. *November*.
Yami, M., Feleke, S., Abdoulaye, T., Alene, A. D., Bamba, Z., & Manyong, V. (2018). African Rural Youth Engagement in Agribusiness: Achievements, Limitations, and Lessons; Mercy Corps. Liberian Youth Reflect on Agriculture Livelihoods. *Sustainability*. https://doi.org/10.3390/su11010185
Zidana, R., Kaliati, F., & Shani, C. (2020). Assessment of youth engagement in agriculture and agribusiness in Malawi : Perceptions and hindrances. *Journal of Entrepreneurship and Management*, *9*(1), 19.
Zougmoré, R., Partey, S., Ouédraogo, M., Omitoyin, B., Thomas, T., Ayantunde, A., Ericksen, P., Said, M., & Jalloh, A. (2016). Toward climate - smart agriculture in West Africa : a review of climate change impacts , adaptation strategies and policy developments for the livestock , fishery and crop production sectors. *Agriculture & Food Security*, 1–16. https://doi.org/10.1186/s40066-016-0075-3

Appendix 1. Co-authorship Form

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Chapter 2, submitted for review: Climate-Smart Agriculture and the Economics of Crop Productivity in Tanzania

Nature of contribution by PhD candidate	Conceptualization, data collection, literature review, empirical analysis, interpretation and writing
Extent of contribution by PhD candidate (%)	70%

CO-AUTHORS

Name	Nature of Contribution
Martin Bai	Sepervision, visualization, proofreading, reviewing and editing

Certification by Co-Authors

The undersigned hereby certify that:

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- that the candidate wrote all or the majority of the text.

Name	Signature	Date
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Chapter 3, submitted for review: Drivers of Youth Intensity of Participation in Agriculture: Insights from Tanzania

Nature of contribution by PhD candidate	Conceptualization, data collection, literature review, empirical analysis, interpretation and writing
Extent of contribution by PhD candidate (%)	70%

CO-AUTHORS

Name	Nature of Contribution
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Chapter 3. Submitted for review: Youth Higher Intensity, Higher Gains? Empirical Evidence from Crop Farming in Tanzania

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Chapter 4, Submitted for review: Impact analysis of agricultural finance on crop productivity among smallholder farmers in Tanzania.

Nature of contribution by PhD candidate	Conceptualization, data collection, literature review, empirical analysis, interpretation and writing
Extent of contribution by PhD candidate (%)	70%

CO-AUTHORS

Name	Nature of Contribution
Martin Bai	Supervision, visualization, proofreading, reviewing and editing

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