



Original Research Article

Socioeconomic drivers for uptake of potato (*Solanum tuberosum* L.) crop intensification innovations in Southwestern Uganda

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The socioeconomic context of farmers plays a complementary role in determining uptake of agricultural innovations. In Uganda, despite considerable agricultural interventions, farmers' adoption rates remain low. This study evaluated socioeconomic factors affecting uptake by systematically analyzing cross-sectional survey data of 265 smallholder potato farmers in three districts of southwestern Uganda, under the Community Action Research Programme Plus (CARP+) Project. Findings of the study indicated that farmers travelled nine kilometers to tarmac roads and four kilometers to input shops with access to credit, income, education level, input markets, and location as the most significant factors for uptake of innovative agricultural practices. The study recommended the development of tailored financial products, income enhancement through value-addition, and improved market linkages to increase agricultural productivity and profitability. The findings indicate a need to invest in agricultural education and capacity-building programs, integrate potato intensification modules into adult education and farmer field schools, and establish decentralized input distribution centres in remote farming communities to improve physical access to input markets, thereby reducing travel time and transaction costs. Additionally, the study emphasized the need to promote integrated support systems through coordinated efforts among extension services, financial institutions, and input suppliers to deliver holistic support to farmers.

Keywords: Agricultural innovation, agricultural markets, CARP+ Project, crop intensification, extension services, financial institutions, markets linkages, transaction costs.

INTRODUCTION

Most smallholder farmers in developing countries are periodically exposed to food insecurity because of socioeconomic issues such as scarcity of land and weak institutional frameworks including limited access to extension and market services (Chamberlin et al., 2014; Chimoita et al., 2019; Nahayo et al., 2017). Consequently, it has been documented that matching up with the ever-

decreasing arable land and to continue feeding the ever-growing population will largely depend on the intensification of the existing agricultural systems (Levers et al., 2016). As such, it is estimated that at least 60% more food will be required to eliminate hunger by 2050 (Kropp et al., 2019). For instance in Africa, 1.8–2.4% more arable land will be lost by 2030 due to urban expansion (D'Amour

et al., 2017). Therefore, interventions and programmes supporting uptake of crop intensification innovations by smallholder farmers are a critical path towards household food security. Uptake in this context means the adoption and sustained use of innovative agricultural practices by using improved inputs such as seeds and fertilizers and improved management practices such as intercropping with appropriate companion crops (Nakibuule et al., 2022; Pretty and Bharucha, 2014). Some crops such as potato have been recommended by diverse scholars in such discourses of household food security (Baddour and Masoud, 2022; Mumia et al., 2018; Muthoni et al., 2022; Sebatia et al., 2014, 2015; Zhang et al., 2017). Because of its fast growing demand for fresh and processed potato products (Mugisha et al., 2017; Kajunju et al., 2021), which is third largest human consumed crop after wheat and rice, potato stands out over many crops due to its remarkable ability to adapt to a wide range of production environments (Campos and Ortiz, 2019).

Potato is historically known as the bread for the poor because of its ability to be grown under a wide range of environments, high nutritional value and ability to provide diverse fresh and processed nutritious foods quickly on less land than any other crop (De Jong, 2016). It is a source of basic nutrients particularly carbohydrates, dietary fiber, vitamins, and minerals such as potassium, magnesium and iron (Zaheer and Akhtar, 2016). Similarly it is also associated with lowering incidents of some chronic and acute disease processes such as hypertension, heart diseases, cancer, neurodegenerative by providing essential antioxidants such as polyphenols (Zaheer and Akhtar, 2016).

In Uganda, various policy strategies to support uptake of potato crop intensification innovations have been promoted by different stakeholders. For instance, the establishment and operationalization of Kachwekano-ZARDI through an act of parliament to guide the production, processing and marketing of potato in the National Development Plans (Najjingo-mangheni et al., 2017), the formulation of the potato Framework Implementation Plan (FIP) to provide an enabling policy environment towards its production, processing and marketing. Similarly, over 20 potato varieties have been released for uptake by National Agricultural Research Organization by the farmers (Kisakye et al., 2020). However, the decision to adopt and sustainably use or try an innovation in a traditional farming system involves knowledge and logical capacity to analyze such an innovation and its combined values (Olum et al., 2020). As such, interventions focusing on the uptake and sustainable use of agricultural innovations largely depend on the socioeconomic contexts of farmers, such as monthly income, household size, market access, belonging to farmer groups, and access to extension (Mugisha et al., 2017). According to Olum et al. (2020), factors such as belonging to a farmer group or association can affect uptake by positively influencing the farmer's willingness to accept (WTA) and willingness to pay (WTP) for agricultural

innovations. Similarly, Mwaura et al. (2021) found that the gender of a farmer, size of household, access to hired labor, farm size, and farming experience were the drivers for the uptake of sole animal manure and animal manure combined with inorganic fertilizer innovation in Upper Eastern Kenya. Similarly a study by Mugumaarhahama et al. (2021) noted that the uptake of improved sweet potato varieties in South Kivu, DR Congo was enhanced by institutional factors such as group membership and access to extension services and recommended for the need to improve extension services to improve uptake among farmers. The authors further noted that socioeconomic factors such as the level of farmer's education, use of hired labor, and high monthly and off-farm income improved uptake, while farmer's age, and reduced farm size negatively affected the uptake of improved sweet potato varieties. However, this finding on farm size contracts other studies such as (Alskaf et al., 2020; Hu et al., 2022). While farmers with larger farms may be more willing to adopt innovations and focus on productive changes for economies of scale, those with small farms are often motivated to adopt input-intensive innovations that can save land and labour as an alternative to increase agricultural output.

Between 2018 and 2021, Makerere University implemented a (CARP+) project in Southwestern Uganda aimed at enhancing potato productivity among smallholder farmers with the use of participatory approaches such as demonstration plots, farmer-field days, and training. This study is focused on socioeconomic factors because they are likely to not only affect uptake but also the continued use of innovations (Alskaf et al., 2020; Hu et al., 2022; Mwaura et al., 2021; Olum et al., 2020; Waaswa et al., 2021). Therefore, this paper contributes to closing this gap by assessing the socioeconomic determinants of potato crop intensification among smallholder farmers in Southwestern Uganda.

Theoretical and conceptual frameworks

The discourse on agricultural transformation and population growth can be traced from the 1800s. Two accounts, including the extensive margin involving expansion into new land and the intensive margin, the intensive cultivation of existing fields (Giller et al. (2021)). Giller et al. (2021) observed that as extensive agricultural expansion yields diminishing returns to labour and capital because the new land is of poorer quality than the land already in use, the intensive account which raises crop yields by practices like better fertilization yields diminishing returns to labour and capital. This discourse was further supported by Malthus population theory alluding to exponential growth in human population and the upper limits of food availability and arable land (Seidl and Tisdell, 1999). Thus, scientific understanding of agriculture transformation has grown considerably since Boserup's seminal 1965 work (Stone, 2001). Boserup observed that when population increases, pressure on land compels farmers to adopt more intensive agricultural practices for survival (Boserup, 1987).

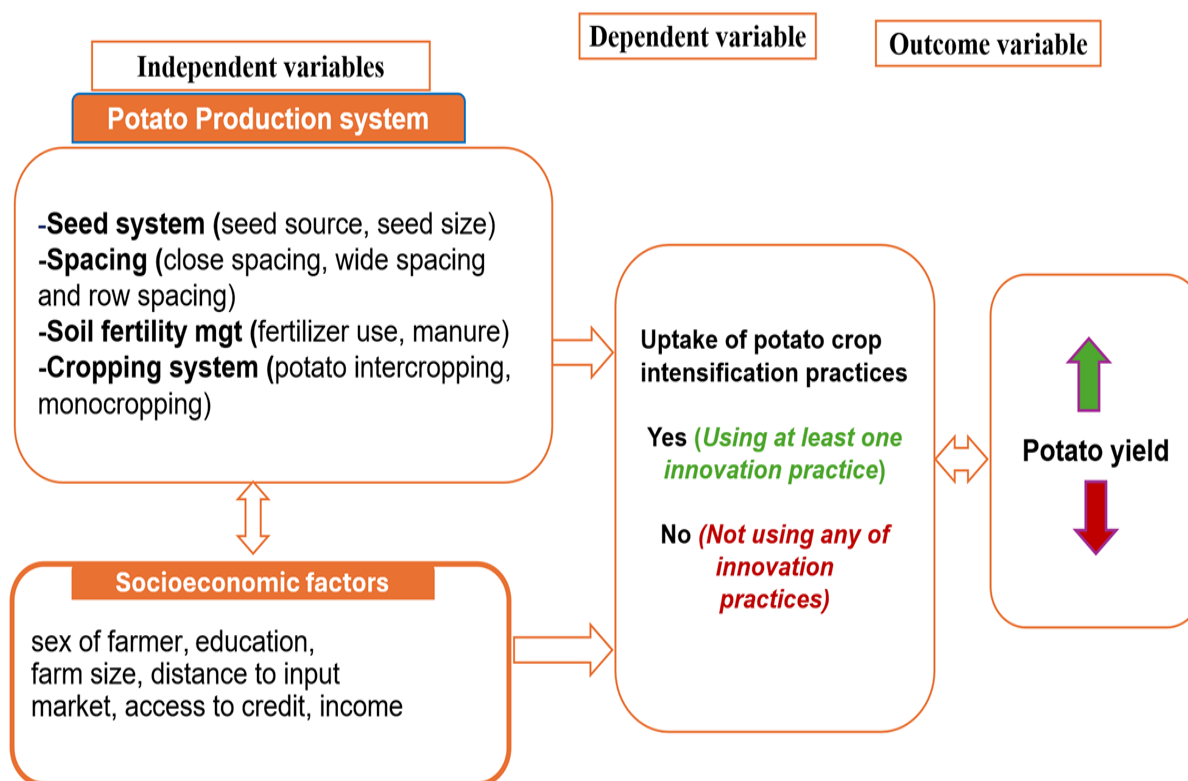


Figure 1: Socioeconomic determinants for uptake of potato intensification innovation

Source: Adapted from Mandal et al. (2022)

Due to the persistent threat of household food insecurity and household income insecurity (Mutea et al., 2019), there has been a focus on crop innovation and uptake of such innovative practices by diverse actors on various agricultural value chains (Anandajayasekeram, 2022; Onumah et al., 2023; Sanya et al., 2017). However, the influence of socioeconomic characteristics of end users such as age, education level and household income particularly for the farmers have not been fully put into perspective (Figure 1).

Socioeconomic factors form part of the human capital that supports investment in innovations and the institutional factors provide an enabling environment that is key for innovation and innovation uptake (Mugumaarhahama et al., 2021). For instance, extension services provide a link where farmers can obtain reliable and affordable information such as market updates (Mandal et al., 2022). Similarly, belonging to a farmer group helps farmers to obtain better markets, quality inputs and also enjoy economies of scale through collective bargaining and marketing (Onumah et al., 2023). Belonging to a Farmer Based Organization (FBO) such as cooperatives, support collective marketing which enhances access to agricultural markets, credit, and extension services (Ifejika et al., 2018). This study, therefore, focuses on socioeconomic contexts to establish their influence on the

uptake of potato crop intensification innovation among household farmers.

MATERIALS AND METHODS

Research Design

A cross-sectional research design was used for this study to optimize on the time constraint. To ensure that the question of the research instrument would illicit the appropriate responses to effectively address the research problem, the questionnaire was developed based on extensive research into crop intensification innovation. A multivariate technique was used to investigate the relationship between the independent variables and the dependent variable utilizing a randomization approach in the study. The study employed quantitative research design, and data were collected through a survey conducted in January 2022. A research design is a blueprint that leads the research process to attain, determine, and assess an explanation to the research question (Sanya et al., 2017). The study aimed to identify the socioeconomic drivers of the uptake of potato crop intensification; thus, this design was most suitable since it collects data that can be used to compare adopters and non-adopters of potato crop

Table 1. Farmers selected for the study

District	Sub County	Target population (N)	Sample size (S)
Rukiga	Rwamucucu	110	86
Kabale	Northern Division	148	106
Rubanda	Bubare	92	73
Total		350	265

Table 2. Apriori expectation of variables included in the model

Code	Predictor variable	Variable description	Expected sign
Ac.Credit	X1= Access to credit	Access to credit, Dummy (yes=1, 0 otherwise)	+
HHincome	X2= HH monthly income	Household income (UGX)	+
HHsize	X3= Persons in household	Number persons in the household	+
Educ	X4= Education of farmer	Years spent in school	+
Sex	X5= Sex of farmer	Sex of farmer, Dummy (Male=1; 0 otherwise)	-/+
Fsize	X6= farm size	Acres of land	+
Dist_market	X7= Dist. to input market	Distance to input market (km)	-
FBO	X8=Membership to FBO	Member of FBO, Dummy (1=Yes & 0 otherwise)	+
Married	X9=Married	Married; Dummy (yes=1; 0 otherwise)	-/+
Experience	X10= Farm experience	Number of years in potato production	+
Non-farm occupation	X11= non-farm occupation	Non-farm occupation of farmer; Dummy (1=Yes, otherwise)	+
Loc-Rubanda	X12= Rubanda	Location in Rubanda, Dummy (1=yes, 0 otherwise)	-
Loc-Kabale	X13= Kabale	Location in Kabale, Dummy (yes=1 ;0 otherwise)	-

intensification innovations at a single point in time. A semi-structured questionnaire was administered to individual respondents to obtain data on different variables under investigation.

Study Area

The study was conducted in the districts of Rubanda, Kabale, and Rukiga in Southwestern Uganda, where about 60% of the total output is produced (Mugisha et al., 2017). These districts were selected after Makerere University launched a potato crop intensification programme. Rukiga District is located between 01°11'S and 30°06'E, covering 426.3 sq. km, with a population of 100,726 and 19,639 households (UBOs, 2016). Kabale district lies between 29°45 'and 30°15' East and 1°00 'and 1°29' South, featuring spectacular valleys (UBOs, 2016). Rubanda District is situated at 1.1682°S and 29.8584°E, known for its green, interlocking, and heavily cultivated hills, with spectacular valleys and an altitude ranging from 1,219 to 2,347 meters above sea level (UBOs, 2016).

Sampling procedure

Three Sub-Counties within the study districts were purposively selected (Bubare Sub-County of Rubanda district, Rwamucucu Sub-County of Rukiga district, and North Division of Kabale district) for this study. From each Sub-County, a parish where CARP+ potato crop intensification demonstration gardens were established was purposively selected as the study site. Guided by Krejcie and Morgan's (1970) table of sample selection, a

sample of 265 respondents was purposively selected because they were presumed to possess the information needed for the study to generate a sampling frame from a total of 350 smallholder farmers (Table 1).

Data collection tools and instruments

Data were collected from 265 smallholder farmers in face-to-face interviews using a semi-structured questionnaire. Broadly, the questionnaire focused on the demographic characteristics of farmers, the level of uptake by farmers, and the socioeconomic contexts of farmers.

The survey instrument was checked for content validity by a panel of three scholars from Makerere University. The experts judged the instrument appropriate for the objective under investigation. The instrument was pre-tested on 30 farmers from Hamurwa trading centre in Rubanda District and these were excluded from the survey for reliability purposes.

Data Analysis

Uptake, measured by a four-point scale (none, one innovation, two innovations, three innovations, and complete package of four innovations), has a categorical and ordinal variable. Because the dependent variable has five ordinal categories, the ordered logit model was used to estimate marginal effects, as described by Muris (2016), who provided an excellent summary of empirical studies that utilize ordered responses across various disciplines of economics. We used the random effects model Hilmer and Hilmer (2014) to investigate the socioeconomic

determinants of potato crop intensification among smallholder farmers. The underlying population regression model estimated is presented in equation (1) below

$$y_{it} = \beta_0 + \beta_1 X_{1,it} + \beta_2 X_{2,it} + \dots + \beta_k X_{k,it} + u_{it} \dots \dots \dots (1)$$

Where;

y_{it} = uptake of any crop intensification practice by house i in time t (with five ordinal categories)

X = set of 13 hypothesized explanatory variables

$\beta_0 - \beta_K$ = set of parameters to be estimated

u_{it} = residual error term

Apriori expectations of variables included in the model

Table 2 summarizes the variables included in the regression model. The choice of explanatory variables was adapted from the literature on agricultural technology.

Access to credit (X_1): Literature suggests that access to agriculture credit increases farm productivity and profit for smallholder farmers because it is an important pathway for farmers to acquire farm inputs such as fertilizers, improved seeds, and hired labor (Makate, 2019; Mugumaarhahama et al., 2021; Shibata et al., 2020). Access to credit improves innovation uptake on the farm because most innovations require initial capital investment which can be acquired through borrowing (Makate, 2019).

Total monthly household income (X_2): Income provides the basis for long-term household poverty reduction through investment in assets, including both natural and human capital (Mugumaarhahama et al., 2021). Studies link agricultural productivity growth to higher cash and in-kind income for poor farmers. This includes increased employment in agricultural markets, even for landless rural laborers, and generally higher wages due to increased demand for both farm and non-farm labor (Tomich et al., 2019).

Household size (X_3): This variable is articulated as the number of members of a household. Studies usually adopt this variable as a proxy for the availability of agricultural labor (Kabir and Rainis, 2015; Kassie et al., 2014) though it also implies spending in the household. This variable was hypothesized to affect the extent of uptake of potato crop intensification initiatives in one way or another.

Years of schooling by the farmer (X_4): Literature presents mixed findings regarding the impact of years of schooling on innovation uptake. Several studies report a positive effect of farmers' years in school on adopting various innovations (Ma et al., 2017; Métouolé et al., 2018; Mugumaarhahama et al., 2021; Ntshangase et al., 2018; Pinthukas, 2015; Unekwu et al., 2020), while others report no significant influence on the adoption of improved farming practices (Kabir and Rainis, 2015; Rodthong et al., 2020). In this study, the number of years of schooling was

expected to boost farming knowledge, thereby contributing to the overall uptake of potato intensification initiatives.

Gender of the farmer (X_5): This is a binary variable, taking the value 1 if the respondent was male and 0 otherwise. Previous literature indicates mixed effects of gender on the uptake of agricultural innovation. Some scholars revealed that female farmers have a better chance of adopting innovations compared to male farmers (Métouolé et al., 2018; Thapa and Rattanasuteerakul, 2011; Unekwu et al., 2020). On the contrary, male-managed plots are more likely to adopt improved farming practices especially those involving minimum soil disturbance, and improved forage technologies, than female managers (Beshir, 2014; Ndiritu et al., 2014; Rodthong et al., 2020). However, authors such as Nigussie et al. (2017) found no effect of the gender of a farmer on the uptake of improved land management such as agroforestry, soil bunds, and stone-faced soil bunds in the highlands of Ethiopia.

Farm size (X_6): Previous studies show both positive and negative influences of farmland size on technology adoption. (Gil et al., 2015; Zeweld et al., 2017) found a positive impact on the uptake of sustainable practices, whereas (Ntshangase et al., 2018) found negative effects on the adoption of organic farming and no-till conservation agriculture. For this study, farm size was expected to positively affect the uptake of potato crop intensification initiatives given the association between land size and investment in technology.

Distance to the agriculture markets (X_7): Farmers from distant places, far away from local markets have limited access to the market, which limits their participation in such market (Mugumaarhahama et al., 2021). Distant places imply rural settings. Such places are less likely to have regular extension visits, have limited access to agricultural inputs such as fertilizers and improved seeds, and experience a poor information flow, as well as inadequate markets for their products (Unekwu et al., 2020).

Frequency of extension visit (X_8): Frequent agricultural extension and education visits are common catalysts for technology uptake among smallholder farmers (Kabir and Rainis, 2015; Kassie et al., 2014; Unekwu et al., 2020). Therefore, this variable was expected to drive the uptake of potato crop intensification initiatives. Agricultural extension education is a crucial means of enhancing human capital by transferring locally relevant information from a global knowledge base (Krishna et al., 2019).

Belonging to the a farmer-based organization (X_9): Farmer-based organizations (FBOs) such as self-help and women's groups, producer organizations and associations, and cooperatives are collective institutions intended to support members' interests (Bizikova et al., 2020; Ifejika et al., 2018). FBOs support small-scale producers in accessing markets, credit, and extension services (Bizikova et al., 2020) as well as in managing shared resources (Okumu and Muchapondwa, 2017). FBOs also enhance members' skills

in production, marketing, and leadership and enhance their psychological well-being (Atieno et al., 2024). Therefore, building on these contributions to farmers, FBOs are core elements and increasingly play an important role in innovation uptake and agricultural productivity (Norton and Alwang, 2020).

Being married (X_{10}): Literature suggests that in most married households, decision-making is joint, and that in the event disagreement, the man is the final decision-maker (Badstue et al., 2020). Thus, married women usually exercise considerable autonomy with respect to small daily decisions, leaving significant decisions regarding resources, expenditure, and matters involving large sums of money to men. Marital status affects an individual's ability to innovate by impacting on their socio-economic support systems, personal priorities, and time availability (Otieno, 2023). Women often need to seek permission from their husbands to make decisions even in areas where they traditionally have decision-making authority (Caroline et al., 2021). Thus, marriage significantly influences women's autonomy and decision-making power, particularly within the household context. While married women may exercise control over minor, day-to-day choices, major decisions particularly those involving significant financial resources are often deferred to their husbands, reinforcing gendered power dynamics. This hierarchical structure not only limits women's ability but also affects their capacity to innovate by constraining their access to resources, decision-making freedom, and time. Addressing these structural inequalities is essential for promoting more inclusive socio-economic development.

Farming experience (X_{11}): Farming experience is usually useful in the early stages of uptake of an innovation when farmers are still testing its potential benefits but abandon the innovation if the benefits are smaller than the efforts used, particularly in incidences of higher labour demand or farm size expansion (Ainembabazi and Mugisha, 2014). Also, farming experience plays a crucial role in farmers' decisions regarding various risk management tools, and they generally adhere to traditional, time-honored tools, thereby developing higher levels of skills (Abbas et al., 2021).

Location (X_{12}): Location plays a critical role in shaping the acceptability and uptake of an innovation, influencing economic activity, cultural norms, institutional support, and the availability of infrastructure. Thus, any effort to promote innovation must be context-specific, recognizing that what works in one place may require adaptation and or may not be viable at all in another. It is believed that what is acceptable in one location may not be in another (Munkombwe et al., 2022). Cultural norms, which are often geographically specific, strongly affect the acceptance of innovations. What is deemed culturally appropriate in one region may be resisted in another due to differing values, belief systems, and traditions. For instance, gender norms in different regions can influence the uptake of agricultural innovations, with women's participation often constrained by local customs (Doss and Meinzen-Dick, 2015). Thus,

cultural disparities mean that innovation must be socially compatible with the target community to be successful (Rogers, 2003).

Furthermore, economic conditions and access to infrastructure vary significantly across locations, thereby affecting the feasibility and appeal of innovations. For instance, rural areas may lack the necessary infrastructure such as electricity, roads, internet facilities, and extension services to support certain agricultural innovations, thereby reducing their relevance or utility (World Bank, 2016). Innovations that thrive in urban centers with robust infrastructure may therefore fail to gain traction in remote areas. Similarly, geographical differences in climate, soil, and ecological conditions can affect the adoption of agricultural innovation. Therefore, innovations must be adapted to local environmental conditions to be effective. For instance, crop varieties suited to temperate climates may not be viable in arid or tropical regions, requiring location-specific innovation (Pretty et al., 2011). Finally, government policy and institutional support systems differ from one region to another, shaping how innovations are introduced and scaled. Areas with supportive policies and innovation hubs tend to experience higher innovation uptake than others (Anderson et al., 2018).

Non-farm occupation (X_{13}). Non-farm occupation serves as a financial buffer during periods of agricultural instability, whether due to market fluctuations, weather extremes, or input shortages. This income diversification reduces the vulnerability of rural households by smoothing income and consumption patterns during shocks. For instance, a study in Zimbabwe found that households with access to non-farm income were significantly more resilient during climate-induced shocks, with female-headed households showing particularly strong welfare improvements (Chikobvu and Mpambela, 2023). Additionally, non-farm income enables reinvestment into agriculture, including the adoption of improved inputs and climate-resilient innovations. A study in Pakistan's Punjab province showed that non-farm earnings significantly contributed to the uptake of soil and water conservation practices by alleviating liquidity constraints and supporting long-term farm productivity (Zulfiqar et al., 2023). Finally, combining farming with non-farm work enhances welfare and ensures continuous farming operations. Asfaw et al. (2022) found that rural households combining climate smart agriculture (CSA) with non-farm employment, achieved significantly better outcomes in terms of poverty reduction and food security in Ethiopia compared to those relying on a single strategy. The complementarity of these strategies provides a multidimensional livelihood approach that is more resilient and sustainable, particularly for smallholder farmers.

RESULTS AND DISCUSSION

Descriptive characteristics of smallholder farmers

Findings revealed that the mean age of respondents was 46

Table 3. Descriptive characteristics of smallholder farmers

Socio-economic characteristics	Mean	SD	p-value
Age of the farmer (years)	46.00	12.65	0.105
Farming experience (years)	11.99	9.97	0.829
Education level of the f farmer	6.60	4.06	0.032
Farm size (acres)	2.65	1.69	0.182
Dist. to agric. Market (km)	3.98	4.52	0.049
Dist. to tarmac road (km)	9.00	8.82	0.012
Dist. to marram road (km)	2.00	2.67	0.000
Dist. to agric. input shop (km)	4.38	4.70	0.334
Dist. to Trading Centre (km)	1.40	1.48	0.179

Source: Field data 2022

years of age (Table 3). This age group is experienced in indigenous knowledge and skills. It falls within the 30-50 year range, considered active in agriculture (Ekunwe and Emokaro, 2009), and also within the 15-64 year economically productive range, which can enhance production if utilized efficiently (Al-Khraif et al., 2022). However, older farmers tend to fear risk, thus develop negative attitude towards new practices (innovations), often perceived as unnecessary (Conway et al., 2021). The finding also revealed that farmers had seven years of schooling (primary education). Education shapes farmers' attitudes by increasing their ability to make informed decisions, leading to greater efficiency, productivity, profitability, and sustainability (Uganda National Bureau of Statistics, 2021). Farmers who complete primary education can read, write and understand most required information for uptake. Thus, crop intensification innovation requires strict adherence to timely and recommended agronomic practices, especially the use of fertilizer and pesticides, and the adoption of improved seeds (Adom and Adams, 2020).

Furthermore, the results revealed that smallholder farmers traveled four kilometers to access the nearest agricultural market and input shop respectively. A shorter distance to the market increases access to market information, and reduces travel time, thereby reducing transaction costs to and from the market, which in turn reduces the overall cost of production. Farmers also travelled nine kilometers to the tarmac road and two kilometers to the marram road. Access to the road is a proxy for access to the market, thereby enhancing the farmers' attitude and market participation. It affects the movement of agriculture products in the market, access to inputs, and market information through easy access to market information, agricultural inputs, and access extension service (Cavallo et al., 2014).

Potato crop intensification innovations adopted by farmers in the CARP+ Project

Findings from the survey indicated that most farmers adopted recommended spacing (75%) and fertilizer use (42%) (Figure 2). Some farmers (9%) had not adopted any

innovation, while the smallest number (4%) had adopted a complete package of all the four implemented innovations. Thus, the adoption rates of 75% for spacing and 42% for fertilizer use, reflect growing awareness and willingness among farmers to embrace yield-enhancing practices. These practices can significantly boost yields and food security. Similarly, a 15% adoption rate of both potato legume intercropping and recommended spacing reflects ecological awareness and efforts to optimize land use and reduce pest pressure. The 4% uptake of complete package suggests that some farmers embrace holistic innovation strategies, that may lead to synergistic benefits and long-term sustainability. The non-adoption rate (9%) indicates minimal resistance to innovation. However, the small percentage adopting the complete package reveals the need for continuous, effective extension services and improved access to farm inputs, especially improved seed.

Potato innovation combinations used by farmers

Findings revealed that the majority of the farmers (50% and 29%) had adopted at least one and two innovations, respectively, compared to three and complete package (8% and 4%, respectively) (Figure 3).

The very low adoption rates of three innovations (8%) and the complete package (4%) highlight serious structural challenges in the potato crop production innovation system. These figures may reflect limited access to inputs such as credit and improved seed, inadequate extension services, or low trust in institutional support. Farmers may also perceive the full package as too costly or risky, amidst other challenges such as climate change and output market fluctuations. Rogers (1995) indicated that risk averse farmers adopt slowly and prefer to observe others before learning and adopting. To address these barriers, policymakers must design holistic interventions that go beyond raising awareness to ensure innovations are affordable, accessible, and relevant to farmers. Policymakers should actively support the bundling of innovations with financial assistance, insurance schemes, or cooperative models to reduce perceived risks and prevent the stagnation of innovation uptake, which is

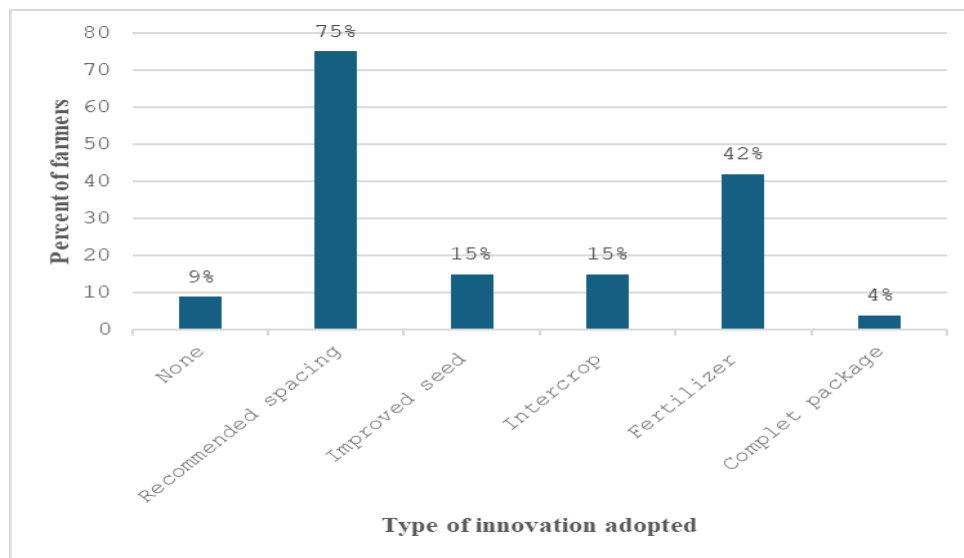


Figure 2: Potato crop intensification innovations adopted by farmers during CARP+ Project

Source: Author's Analysis using Excel software

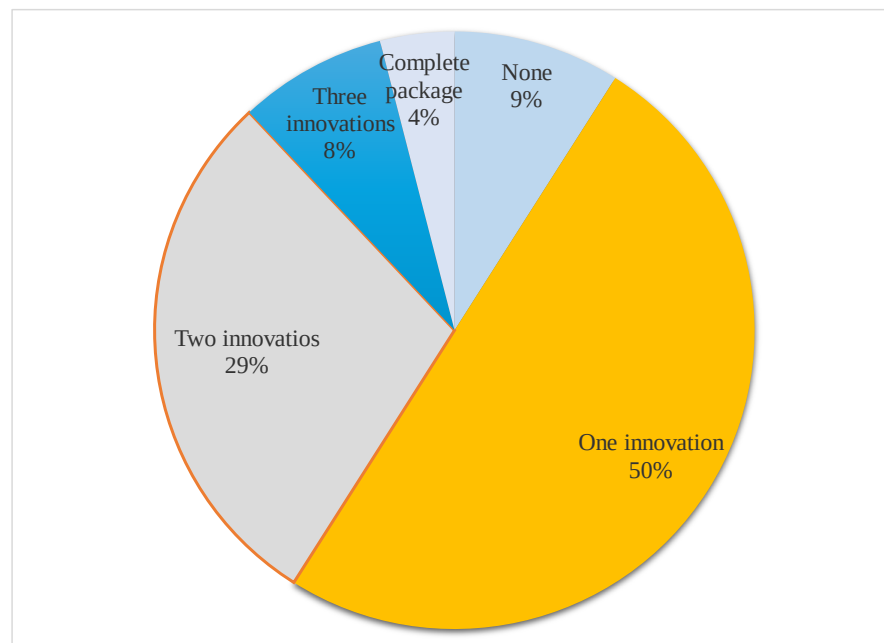


Figure 3: Potato innovation combinations used by farmers

Source: Author's Analysis using Excel software

essential for improving productivity and rural development.

Average potato yield obtained by different farmers adopting different potato crop innovations

Survey results showed that whereas the farmers who had adopted a complete package harvested 44-100kg bags of potato per season, those farmers who had not adopted any

of the innovations harvested 14-100kg bags while adopters of at least one innovation harvested 20-100kg bags per season (Figure 4).

These findings align with Tadele (2017), who found that the productivity of cassava and maize increased by 90% and 80%, respectively, with improved practices. Shrestha and Subedi (2019) similarly noted that crop intensification raises annual harvests per plot, resulting in increased production and income opportunities for farmers.

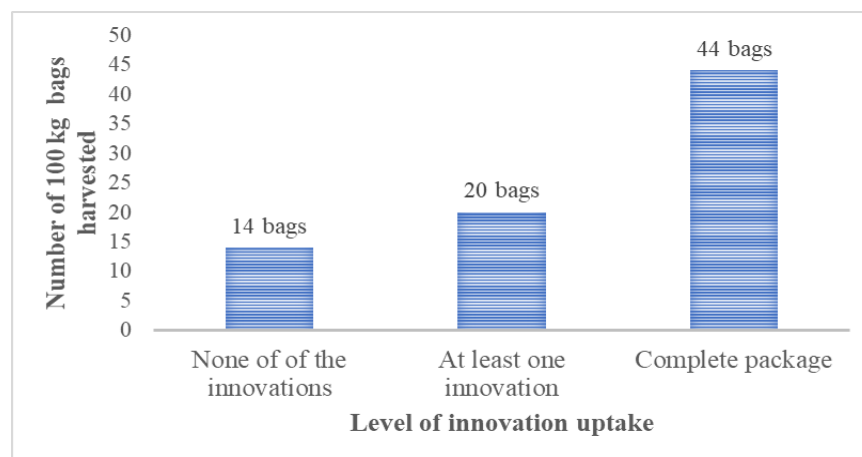


Figure 4: Level of uptake and yield obtained by smallholder farmers per season

Source: Author's analysis using Excel software

Table 4. Estimated marginal effects from the ordered logit estimation for socioeconomic drivers for the uptake of the potato crop intensification

Variable description	Number of potato innovation practices adopted				
	None (non-adopter)	One	Two	Three	Four (Complete package)
	dy/dx				
Access to credit; Dummy (1=0, 0 otherwise)	-0.053**	-0.099**	0.084**	0.042**	0.027**
Household income (UGX)	0.027*	0.051*	-0.043*	-0.021*	-0.013*
Household size	-0.004	-0.008	0.006	0.003	0.002
Education level (no. of years in school)	-0.004	0.007*	0.006*	0.003	0.002
Sex of farmer; Dummy (Male =1, 0 otherwise)	-0.016	-0.031	0.026	0.012	0.008
Farm size (Acres)	0.000	0.000	-0.000	-0.000	-0.000
Dist. to input market (kms)	0.002**	0.005**	-0.004***	-0.002**	-0.001**
FBO membership; Dummy (yes=1, 0 otherwise)	0.016	0.031	-0.004***	-0.013	-0.008
Married; Dummy (yes=1, 0 otherwise)	0.042	0.077	-0.026	-0.032	-0.021
Experience in potato production (years)	-0.000	-0.001	-0.066	0.000	0.000
Non-farm occupation	-0.026	-0.048	0.041	0.020	0.031
Location in Rubanda; Dummy (yes=1, 0 otherwise)	-0.083**	-0.0152**	0.129**	0.064**	0.041**
Location in Kabale; Dummy (yes=1, 0 otherwise)	-0.035	-0.065	0.055	0.027	0.018

LR χ^2 (13) = 31.69

Prob > χ^2 = 0.0027

Log likelihood = -316.49613

Pseudo R^2 = 0.0477

According to Plan International's Global Child Protection Area of Responsibility (2022), yield determines food availability on the supply side of food security, which is directly influenced by the level of food production. Therefore, increased yields provide smallholder farmers with greater food access, both from their own stocks and from higher incomes resulting from potato sales.

Determinants for the uptake of the potato crop intensification innovations

Estimates of marginal effects (dy/dx) are derived from an ordered logit logistic regression model. This analysis

identifies drivers of uptake for potato intensification innovation in Southwestern Uganda. The results show four significant factors influencing smallholder household uptake: household size, monthly income, distance to the nearest agricultural market, and number of extension visits (Table 4).

The study revealed that access to credit reduced the probability of implementing none or only one practices while it increased the likelihood of adopting two, three or all the four practices. Easy access to credit enables farmers to acquire farm inputs, including fertilizers, improved seeds, and hired labor (Makate, 2019; Mugumaarhahama et al., 2021; Shibata et al., 2020). It can also provide initial and

working capital investment, thus promoting the adoption of innovations (Makate, 2019). Therefore, credit not only enables initial innovation uptake but also enables the scaling-up of practices essential for productive farming systems.

Findings revealed that as household income increased, the likelihood of not adopting any innovation and the uptake of just one innovation increased. However, higher income reduced the likelihood of adopting at least two, three, or the full package of four innovations that support potato crop intensification. Contrary to this finding, much of the literature asserts that household income is a key enabler of innovation uptake. Higher incomes allow farmers to afford riskier investments and purchase complementary inputs such as fertilizers, improved seeds, and hire labor, thereby overcoming time and labor constraints (Makate, 2019). However, households with higher income levels may be more likely to adopt just one or no innovations at all. Those with moderate incomes often adopt multiple practices. This may be because wealthier households diversify their income and focus less on agriculture. They may rely more on non-farm enterprises, formal employment, or remittances, thus reducing their dependency on farming and the need for agricultural innovation (Asfaw et al., 2022). Wealthier households might choose selective innovations that align with their convenience or status, rather than full packages that demand more labor, coordination, or management effort. For instance, they might adopt improved seed but avoid intercropping and recommended spacing, which are more labor-intensive. Reduced uptake of multiple innovations among higher-income households may also reflect context specific or behavioral factors, such as limited extension services that prevent awareness of the combined benefits of adopting innovations in packages.

Furthermore, every year a farmer spent in school reduced the likelihood of not implementing any innovation but increased the likelihood of adopting at least one or two innovations. Formal education improves literacy, numeracy, and problem-solving skills, enabling farmers to understand and apply new techniques. Educated farmers are more likely to seek out and interpret extension materials, attend training sessions, and engage with digital platforms that also foster better risk assessment, making farmers more comfortable with trying at least one or two innovative practices. Studies such as Ma et al. (2017), Métouolé et al. (2018), and Unekwu et al. (2020) show a statistically significant positive correlation between years of schooling and the likelihood of adopting innovations. Mugumaarhahama et al. (2021) found that educated farmers were more likely to engage with potato intensification initiatives, even if only partially. Finally, being located in Rubanda increased the likelihood of implementing two, three and a complete package of practices. This is explained by proximity to inputs, mainly improved seeds and extension services from Kachwekano-ZARDI. This finding aligns with the literature, including Ma et al. (2017); Unekwu et al. (2020), who noted that physical

access to research institutions correlates with higher adoption rates of improved practices, and Ntshangase et al. (2018), who highlights that location near demonstration plots or research centers increases exposure and trust among farmers to implement multiple innovations.

CONCLUSIONS AND RECOMMENDATIONS

This study highlights the key factors driving uptake of potato crop intensification innovations among smallholder farmers in Southwestern Uganda. The findings emphasize the crucial role of access to credit which enables both the initial adoption of innovation and subsequent scaling-up. Education level, household income, proximity to input markets and location also influence farmers' decisions on adopting intensified potato crop production practices. This study concludes that access to credit and household income enables farmers to invest in essential inputs such as improved seeds and fertilizers, thus promoting the uptake of intensification innovations. Education level also supports farmers' decision-making processes to invest in potato crop intensification practices. Also, significant distances to input markets pose substantial challenges by increasing transaction costs and travel time, thus discouraging the uptake of such innovative practices.

Based on these findings, the study recommends addressing both economic and logistical barriers while leveraging education as a catalyst for informed investment in potato intensification. Strengthen rural credit access mechanisms by developing tailored financial products for smallholder farmers, and promote farmer cooperatives and savings groups to improve collective bargaining and access to formal credit institutions. Enhance household income through value addition by facilitating market linkages and training farmers in post-harvest handling, thereby increasing profitability from potato production. Invest in farmer education and capacity building by expanding agricultural training programs that focus on economic decision-making and innovation adoption. Additionally, integrate potato intensification modules into adult education and farmer field schools to improve uptake. Enhance physical access to input markets by establishing decentralized input distribution centers in remote farming communities, thereby reducing travel time and transaction costs. Promote integrated support systems through coordinated efforts among extension services, financial institutions, and input suppliers to deliver holistic support to farmers, and use ICT platforms to disseminate information on input availability, credit options, and best practices.

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Conflict of interest

The authors declare no conflict of interest

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