AGRICULTURAL TECHNOLOGY ADOPTION, EXTENSION SERVICE, IMPACT ON PRODUCTIVITY: CASE STUDY OF SMALLHOLDER FARMERS IN UGANDA.

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1.0 INTRODUCTION

For next few decades, agricultural productivity will have to increase substantially especially in Sub Saharan Africa where productivity is low and population is increasing. Population has been projected to increase to above 9 billion by 2050 while food production needs to increase by about 70% to feed the growing population. This will have to be accomplished in a sustainable way and not by increasing competition for land, water, and energy and in the context of a changing climate (world bank, 2019).

Crop productivity weakness across Sub Saharan Africa is not only influenced by poor soil in many countries but by the limited use of inputs needed to increase productivity. These inputs include the use of fertilizers, improved seed, pesticides, irrigation (CIMMYT, 2015). Sustainable intensification, requiring the use of modern technologies such as inorganic fertilizer and hybrid seeds, and agricultural practices such as irrigation and row planting are regularly prescribed as an efficient ways to improve crop yields (Tilman et al. 2011).

Attempts to understand the factors that determines household decision to adopt different agricultural practices and their impact on productivity has been documented in a range of previous studies. (Benin et al. 2011 ; Okoboi et al. 2012 ; Sebaggala & Matovu, 2020 ; Alun Thomas,2020).

previous studies use econometric methods that do not account for farmers' unobserved heterogeneity which leads to inconsistent and biased parameter estimate if not controlled for. Also, previous adoption studies have focused on either a single new technology or specific crop (improved seed and inorganic fertilizer, extension services, organic fertilizer, pesticide) or a set of modern technologies treated as a unique bundle. However, farmers often combine different new technologies in order to maximize the potential benefits of each of them. In other words, the adoption decision can be described as a multivariate adoption than a univariate process.

In this paper the issue is addressed by using multivariate probit approach to estimate the determinant of agricultural practices by small holder farmer (Improved seed, inorganic fertilizer, organic fertilizer, pesticide and participation in national agricultural advisory services). This account for interdependence and simultaneous agricultural practices adoption decision. To account for endogeneity problem during the estimation of impact of agricultural practices adopted on yield probit two-staged least squares was used. The empirical approach is applied to smallholder farmers in Uganda using the second visit 2018/19 Uganda National Panel Survey (UNPS).

1.1 Problem statement

Agricultural Innovation adoption is an important factor affecting the productivity of agriculture and the economics of the food sector is SSA. The sector has not experienced tangible increase in productivity in the past half century, partly due to low adoption rates of modern input. (Svensson & Yanagizawa-Drott, 2014).

Many of the household in Sub Saharan Africa depend on Agricultural for living, but the continuous low agricultural productivity and insufficient transformation of the food system are important impediment to improving welfare. (K.Fugile & A.Nin-pratt, 2012).

As the largest country among the sub-Saharan African (SSA) countries, Uganda faces a severe problem of agricultural productivity and food insecurity.70% of Uganda's population was engaged in agriculture but on small and low productivity farms. Agricultural sector in Uganda accounted for 28% of their GDP basically 50% from export revenue and 50% on land area. Uganda is endowed with favourable natural resources, varied climate conditions needed for wide variety of crops and livestock but the growth in Agricultural total factor productivity (TFP) was -3% between 2000 and 2010. (World Bank, 2019).

For many developing countries including Uganda increasing agricultural productivity is one of the main goals of policy makers and there developing partners. Agricultural technology adoption has been seen as pathway for fighting low productivity and overcoming extreme poverty through direct and indirect effects (J. Becerril & A. Abdulai, 2010; World Bank,2017). Increase in productivity and lower per unit costs of production which raises income of farmer that adopt agricultural technology is regarded as the direct effect and the indirect effect depend on demand elasticity, outward shift in supply which can lower food prices and increase in productivity resulting to demand for labor translating into increased employment, wages and earnings (Kassie et al.,2011).

The low productivity in SSA has been attributed to so many things like land degradation due to soil erosion and nutrient depletion, population pressure, inadequate rainfall, misappropriation of agricultural technologies and mismatched agricultural policies. Based on this SSA governments and their development partners have allotted substantially resources to increase agricultural productivity, increase economic growth and improve environmental conditions. Different agricultural extension services such as the National Agricultural Advisory Services (NAADS) in Uganda, Agricultural Marketing and Irrigation programs in Tanzania, Soil and Water conservation programs in Kenya has been put in place in order to increase agricultural productivity and improving farmer's welfare. For this program emphasis had been on adoption of yield enhancing agricultural technologies like improved seed, pesticide, inorganic fertilizer and irrigation expected to improve the wellbeing of adopters.

In spite of the benefit farmers can get from the modern technology, adoption rate is still low and it affect their welfare (Kassie et.al.2011 & N. Mukasa,2018).

1.2 The Uganda's National Agricultural Advisory Services Program

The programme is a 25 years public-funded private sector-contracted extension system that is being implemented in phases which was introduced by the Act of 2001. The first phase was from July 2001 to June 2010, second phase was from July 2010 to June 2015. The programme reached 545 sub counties (83% of total sub counties in Uganda) at the end of 2006/7 (Benin, et al., 2011).

The program is a farmer led agricultural service delivery system targeting the poor subsistence farmers with emphasis on women, youth and people with disabilities. (Kwapong & Nkonya 2015). The programme was designed to build farmer capacity to form and coordinate farmer associations, demand advisory services and adopt improved agricultural technologies and practices through demonstration by model farmers in the community. The demonstration sites were managed by six model farmers per parish (second-tier local government administration). The 2005/6 implementation guidelines mandated program administrators to distribute free or subsidized inputs to more participant per parish (Okoboi,2013).

The programme is mainly funded by grants and loan from long-term multilateral and bilateral credit financing. For the phase ll Government was to fund the program through annual budgetary allocations and from already available physical assets such as office equipment and infrastructure rollovers from NAADS phase 1, but this funding component was removed due to the dismal performance by local governments and farmers. The figure below explains how the program was funded in phase l and phase ll.

Source	NAADS I (2001/2–2009)		ATAAS (NARO & NAADS II) (2010/11–2014/15)	
	Millions of Dollars	%	Millions of Dollars	%
International Development Agency (IDA)	45	41.7	120	18
International Fund for Agricultural Development (IFAD)	17.5	16.2		
Global Environment Facility (GEF)			7.2	1.1
Bilateral agencies and IFAD	23.34	21.6	41	6.2
Government of Uganda	9.12	8.5	497.3	74.7
Local government (district and subcounty)	10.8	10		
Farmers' organizations	2.16	2		
Total	107.92	100	665.5	100

Figure 1:The NAADS Financing Plan (millions of US$)

Source: Okoboi et al.,2013 based on World Bank 2001;2010

1.3 Purpose of Research

For policy improvement that will enhance agricultural production systems, poverty reduction, detailed information on factors influencing household's modern technology adoption decision is required. This paper will contribute to literatures that attempt to better understand agricultural technology adoption, participation in extension service adoption and their impact on productivity among small holder farmer in Uganda.

The main objective of this thesis is to understand the main drivers for adoption of agricultural practices and how the use of different agricultural technologies and Participation in National Agriculture Advisory services programme impact yield of smallholder farmer in Uganda.

The subobjectives are threefold:

(1) Determinant of adoption of improved seed, inorganic fertilizer, organic fertilizer, pesticide and participation in NAAD
(2) The effect of technology adoption on yield
(3) The effect of participation in NAAD on yield

Accordingly, three main hypotheses are defined:

Agricultural technology adoption as been described as a multivariate adoption as farmers frequently combine different new technologies in order to maximize the potential benefits of each of them.

H_1: There is interconnectedness amidst agricultural practices adopted by farmers

H_2: Adoption of modern agricultural technology increases farmer's yield

H_3: participation in NAAD increases farmer's yield

These hypotheses are tested using multivariate probit model and Probit Two Stage Least Square to cross-sectional data from Uganda National Panel Survey (UNPS).

1.4 Outline

The rest of the thesis is structured as follows: Section 2 examines the literature on agricultural technology adoption and the theory behind agricultural technology adoption, Extension service and their impact on yield. Section 3 presents the theoretical model and conceptual framework and describes the data. It follows the specification of the empirical models and the methodological approach. Section 4 present and discuss the results. The last section draws policy recommendations.

2.0 LITERATURE REVIEW

2.1 Reviews on determinants of Agricultural technology adoption

2.1.1 Factors affecting the adoption of Agricultural technology and Participation in NAAD

Agricultural technology has been seen by governments and development organizations as effectual ways to improve farm productivity and decrease poverty. But adoption remain low (Ruzzante et al.,2021).

Despite the resources spent on the public extension system in Uganda, the adoption of improved crop varities is limited adoption of improved crop varieties, and input use had been reported to be generally very low. 23% of agricultural households in Uganda were using improved seeds in 2018, while a much lower proportion (12%) received advisory services (Uganda Bureau of Statistics, 2018). In fact, the drop rate of initials adopter of improved agricultural technology are high. For instance, Kijima et al (2011) shows that about 50% of farmers who adopted the high yielding rice variety (New Rice for Africa—NERICA) abandoned the variety within two years. This is the situation despite widespread evidence that returns to agricultural technology adoption are high in Uganda. World Bank showed that adoption of improved seeds was associated with a 21% increase in crop yields for Ugandan farmers (World Bank, 2006; Kasire, 2013).

Several empirical studies had been done to understand what influence farmers decision to adopt using three paradigms: the innovation-diffusion paradigm, the adopter-perception paradigm and the economic constraints paradigm (Ruzzante et al.,2021). For innovation diffusion paradigm, information has been seen as the main parameter that controls the spread of an innovation through a society. Societies are said to consist of range adopter categories, from innovators, early adopters to laggards which are different in personality, socioeconomic and communication attribute. (Prager & Posthumus, 2010).

The adopter perception paradigm assume that it is the perceived need to innovate and the perceived attributes of innovation that influence adoption. The characteristics of the innovation, its delivery combined with contextual and individual factors influence adoption (Adeshina & Zinnah,1993; Prager & Posthumus,2010). The economic constraints paradigm assume that farmers aim to maximize utility and that unequal resource endowments leads to observed patterns of adoption. This paradigm emphasizes on the role of economic factor at the individual level in determining adoption decisions (W.Negatu & Parikh, 1999).The determinant of adoption can be explained by any of the three paradigms.

Also, there are many categories of grouping determinants of technology adoption but no clear distinguishing feature between variables in each group (Mwangi & Kariuki, 2015). For example, Akudugu et al. (2012) grouped them into three categories namely: social, economic and institutional factors. Lavison (2013) classified them into social, economic and physical category while McNamara, Wetzstein and Dounce (1991) categrorized the factors into, farmer characteristics, farm structure, institutuional characteristics and managerial structure. Factors such as farmer education, household size, access to credit, land tenure, land size, access to extension services and organization membership have been found to have positive relationship with the adoption of many agricultural technology (Uaiene, 2011; Mwangi and Kariuki, 2015; Ruzzante et al.,2021).

An important determinant of the adoption of a new technology is the net benefit farmer get from adoption, inclusive of all costs of using the new technology (Foster and Rosenzweig, 2010). High cost of agricultural inputs (seeds, chemicals and fertilizer has been reported as constraints to adoption of agricultural technology (Kinyangi, 2014). This is supported by other previous studies such as Chi and Yamada 2002, Nkonya et al., 2008 on determinants of technology adoption. In addition, the eradication of subsidies on prices of fertilizers and seeds since the 1990s due to the World Bank sponsored structural adjustment programs in sub-Saharan Africa has increased this constraint (Muzari et. al. 2012). High cost of labor and other inputs, unavailability of demanded packages and untimely delivery as been reported by Makokha et al. (2001) as the main constraints to fertilizer adoption in maize production in Kiambu county, Kenya. Wekesa et al. (2003) found that high cost of seed and fertilizers and non-availability of seeds as a factors responsible for limited rate of adoption of improved maize variety in coastal lowlands of Kenya.

Small farm size encourage adoption of agricultural technology mostly in the case of an input-intensive innovation such as a labour-intensive or land-saving technology. Small holder farmers adopt land-saving technologies such as greenhouse technology, zero grazing as an alternative to increased agricultural production (Nguluu et. al, 1996).

Some technologies are termed as scale-dependent because of the great importance of farm size in their adoption (Genius et al. 2010). Large farm farmers are likely to adopt a new technology as they can attempt the use of new technology with a portion their land compare to farmers with less farm size.

Access to extension services assist in disseminating information about new agricultural technology leading to adoption. Farmers are mostly educated about the existence as well as the effective use and benefit of new technology through extension agents. Participation in agricultural training and short-term extension programs is associated with higher use of inorganic fertilizers. Extension agent acts as a link between the innovators of the technology and users of that technology (Obayelu, 2017). Several studies have reported a positive relationship between extension services and agricultural technology adoption. Examples are ; Adoption of improved maize and land management in Uganda by Kuuma 2005; Adoption of Imazapyr-Resistant Maize Technologies (IRM) by Mignouna et al. 2011; Adoption of modern agricultural technologies in Ghana (Akudugu et al. 2012). This is because exposing farmers to information based upon innovation-diffusion theory is expected to promote adoption (Obayelu, 2017). It is possible that , the influence of extension agents can offset the negative effect of no years of formal education in the overall decision to adopt some technologies (Kuuma, 2005).

Evaluation studies of the NAADS programme reveals that the NAADS programme has had little impact on agricultural technology adoption in Uganda. particularly, the study by Benin et al (2011) based on panel survey of farmers in 2004 and 2007 reported that farmers participating in NAADS programmes were significantly more likely to adopt the recommended planting and spacing practices only. There were no significant differences between NAADS farmers and non NAADS farmer on adoption of improved seeds and livestock breeds, pesticides and inorganic fertilizers. The authors attribute the above results to the fact that adoption of agricultural technologies after extension advice requires resources, and in case of binding credit constraints, the envisaged change may not materialize. Also, their probit results show that the longer the NAADS program has been in the subcounty, the less likely farmers are to participate directly in the program, suggesting that farmers may be giving up direct participation with time. This is not surprising and is likely due to several factors. Generally, it reflects declining net gain from direct participation. It is possible that farmers may not have received grants they expected to receive or that the cost of participation, including membership fees, has exceeded the benefits from any grants and other benefits received.

Credit assess has been found to be an important factor influencing the agricultural technology adoption decision of smallholders (Lavison, 2013). Credit can speed up the purchase of needed agricultural inputs by farm households and also influence their capacity to effect long term investment in their farms (Obayelu, 2017).

Most adoption studies measure human capital through the farmer's education, age, gender, and household size (Lavison, 2013; Namara et al. 2003; Okunola and Akinwalere, 2011). Education level of farmers has been predicted to have a positive influence on farmers' decision to adopt new technology (Obayelu, 2017). It is expected that the level of education of a farmer increases his ability to efficiently use information relevant to adoption of a new technology (Ajewole, 2010). For instance, a study on adoption of fertilizer conducted by Ibrahim (2013), shows that the level of education had a positive and significant influence on adoption of fertilizer. This is because higher education influences respondents' attitudes and thoughts ,making them rational and able to examine the gain of new technology (Garforth et al. 2003). But recent study by (Usman et al.,2020) found that education has negative effect on the adoption of Inorganic fertilizer, organic fertilizer and improved seed.

Interaction with extension services (Lee, 2011, Karugia et al. 2004) and peer-group behaviour (Loevinsohn et al. 2012) positively impact farmers' technology adoption decisions.

2.1.2 Factors affecting the adoption of Pesticide use

According to Andersson and Isgren 2021, lack of knowledge about the specific types of pests that attack the crops, as well as access to technical support on pest control was indicated as a serious constraint to effective pest management. Use of synthetic pesticides to treat crop pests is a practice that recently has increased considerably among Paya farmers. In their report, majority of pesticide users (96%) report that they regularly apply pesticides as a preventative measure, rather than treat crops only once there are signs of pest damage. Also, the information farmers receive from pesticide sellers regarding proper handling of pesticides is reported as largely inadequate. The findings further demonstrate that farmers' current pesticide use and handling practices entail substantial risk to human and environmental health due to lack of access to technical support and protective measures. Many have experienced direct health impacts as a result of pesticide exposure, including skin irritation, coughing, headache, dizziness, breathing difficulties and nausea. Also, a range of environmental impacts, such as poisoning of domestic animals, loss of aquatic fauna, reduced soil life and gradual development of pesticide resistance, are witnessed locally.

One of the important goals of IPM is to control pests while reducing the use of synthetic pesticides. Knowledge of social, economic and institutional factors that influence farm-level decisions to adopt pesticides may suggest different targets and strategies for disseminating IPM. Previous studies have indicated that more intensive use of pesticides is often associated with greater knowledge and awareness of non-chemical control strategies such as IPM (Erbaugh et al., 2001; Morse and Buhler, 1997). Among the personal background variables explaining total pesticide usage, educational level was the only statistically significant predictor. It was revealed that higher levels of education and extension contact facilitate greater pesticide use, but economic barriers do not restrict pesticide adoption (Erbaugh et al., 2002).

To better understand what influence farmers decision on adopting agricultural practices, this paper study adoption of agricultural technology by categorizing the factor into farm household characteristics, farmland characteristics and economic and social capital through the economic constraint's paradigm. It contributes to literatures by including extension services (participate in NAAD) as one of agricultural practices adopted compare to other literature that includes it as a factor in determining adoption.

2.2 Review of impact of technology adoption and NAADS on productivity

2.2.1 Impact of Technology adoption (improved seed) on productivity

The Green Revolution of the 1960s introduced the spread of new crop varieties, fertilizers, and many other agricultural technologies to farmers in developing countries, specifically in Asia and Latin America. Although, there are large differences in technology adoption across and within regions (Keith et. al. 2020). Existing literature has attributed the adoption of improved seeds to improved welfare and poverty reduction through higher productivity and/or increased returns (Awotide et al. 2016; Mendola, 2007; Verkaart et al., 2016). However, productivity has remained relatively low which leads to low incomes and increased poverty among farmers. In Nigeria for example, despite the adoption of improved varieties and the consequent positive impact on productivity, poverty among farmers is still highly endemic and rampant in rural areas.

Awotide et al. 2016 finds that yield of traditional rice varieties in Nigeria is extremely low compared with that of the improved varieties, and expects that adopters of improved varieties should be better off compared with the non-adopters (measured by means of certain welfare improving indicators). It was posited that higher adoption of improved rice varieties would lead to an increase in rice yield and rural farmers could, consequently, have marketable surplus which would lead to an increase in household income and by extension generate improvement in household's welfare.

According to Kassie et. al. 2011, adoption of improved groundnut varieties in Uganda significantly increases household crop income, enhancing a household's chances of escaping poverty. Improved groundnut varieties have the potential to increase crop income in the range of $130 to $254 and to decrease the poverty incidence, measured by headcount index, by 7–9 percentage points. In their findings, it was concluded that adopting improved groundnut technologies can be an important pathway for smallholder farmers to increase their agricultural income and to escape poverty. Technology adoption, however, is constrained by unequal availability of improved seeds, lack of development of market infrastructure, and limited access to information and agriculture extension services.

Okoboi et al. 2012 reported that on average, farmers in Uganda who use improved inputs such as certified seed, fertiliser, fungicides and/or traction get high yield but low profit, which is in contrast to the yield and profit of farmers who do not use these inputs.

Simtowe et al. 2019 examined the impact of drought-tolerant maize varieties (DTMV) on productivity in Uganda and finds that adoption of DTMV increases productivity. Also, results showed that the impact (for adopters) is higher when compared to local varieties with yields increasing by 18.9% compared to the 14% when DTMV yields are compared against other (non-DTMV) improved varieties. This compares reasonably to earlier estimates of a 25% yield advantage of improved maize varieties over local maize varieties in Africa (Smale et al., 2003).

2.2.2 Impact of Technology adoption (inorganic and organic fertilizer) on productivity

The use of fertilizers has been comfirmed to be an important drivers of agricultural productivity among farmers in sub-Saharan Africa. According to Sebaggala and Matovu, 2020, the coefficients on use of organic and inorganic fertilizers were positive and statistically significant. They reported that households who use both organic and inorganic fertilizers were 11% and 17% more productive, respectively, than those who did not use fertilizers.

Nkonya, et al. 2005 also observed that several inputs and land management practices had a positive impact on crop productivity. These inputs include pre-harvest labor, purchased seeds, inorganic and organic fertilizers, and incorporation of crop residues. The positive impact of seeds and inorganic fertilizer were also consistent with the findings of Pender, et al. (2004).

However, Nkonya, et al. 2005 noted that the positive impacts found for organic fertilizer and crop residues contrasts with the results of Pender, et al. (2004) and Nkonya, et al. (2004b), who found insignificant impacts of organic fertilizer on crop production, perhaps because of differences in the sample frames or the way organic fertilizer was measured in these different studies. Use of inorganic fertilizer appeared not to be profitable where it is being used. The low profitability of inorganic fertilizer explains its low adoption in Uganda, and suggests that major improvements in the market environment facing Ugandan farmers are a prerequisite for substantial adoption to occur. Similar findings were also reported by Pender, et al., (2004) and Woelcke (2002).

In addition to the fact that Uganda is a landlocked country, there are many other factors that contribute to the high cost of fertilizer in the country relative to its neighbours (Nkonya, et al. 2005). For example, Omamo (2002) observed that Uganda fertilizer procurement and distribution is dominated by retail-level trade and high prices that discourage farmers to use fertilizer and low net margins that discourage traders to market fertilizer (Omamo 2002). All these factors contribute to the low profitability of fertilizer in Uganda that was observed by Nkonya, et al. 2005.

2.2.3 Impact of NAADS on productivity

The NAADS program had been evaluated twice by Benin et al., in 2007 and in 2011. In the first phase of evaluation, Benin et al. (2007) applied simple difference in means analysis on cross-sectional data to compare the adoption of technology and new agricultural enterprises, productivity, commercialization, income, food security and nutrition across NAADS and non-NAADS households. NAADS was observed to have had a substantial positive impact on the availability and quality of advisory services provided to farmers and that the programme promoted the adoption of new crop and livestock enterprises, including modern agricultural production technologies and practices; and led to a greater use of postharvest technologies and commercial marketing of commodities. However, there was no significant changes in yield between NAADS and non-NAADS households for most crops. In the second round of the NAADS evaluation, Benin et al. (2011) used the propensity score matching (PSM) and average treatment effect on the treated methods on data collected in 2005 and 2007. They reported that NAADS had a great impact on access to advisory services and statistically significant effect on the adoption of new crop, livestock enterprises and the improved agricultural technologies and practices considered. But, there is no significant differences in yield between participant and non-participant of NAADS. Results of the combined Second-stage estimator and PSM revealed mixed results. There was substantial increase between 2004 and 2007 in both crop and livestock productivity, although the percentage increments were generally greater in the case of livestock productivity. For direct participants of NAADS, livestock productivity was more than double for crop productivity. Although non-participant NAADS households realized large increases in crop and livestock productivities, those located in areas where the NAADS program was never implemented realized relatively small increases in crop and livestock productivities, around 30 percent. Adoption of the improved agricultural technologies and practices requires farmers to have financial resources and/or credit facilities from which to acquire them. Therefore, the positive impact of the NAADS program on adoption of recommended planting and spacing practices is not surprising, because such practices may require only additional labor at most. The question is whether greater adoption of recommended planting and spacing practices is sufficient to drive the expected changes in subsequent outcome indicators, including increased productivity, commercialization of production, incomes, and welfare (Benin et al., 2011, Okoboi et al. 2012).

Okoboi et al. 2012 used the difference-in-differences (DID) method based on PSM to evaluate the effect of participation in NAADS on household access to extension services, the use of improved technologies, productivity, market participation, and income and poverty levels. The DID revealed mixed results for the impacts of NAADS on productivity. The changes in yield for potato, banana and maize were negative and statistically significant between participating and non participating household. For groundnut, farmers participating in NAADS exhibited a significantly higher increase in yield compared with non-NAADS households. Positive and statistically significant changes was found for coffee and beans yield for households that participated in NAADS when compared with non-NAADS households. Participants in Focus group discussions attributed the poor-quality inputs supplied to beneficiaries to the negligible impact of NEEDS. Delayed supply of inputs at the end of the rainy/planting season was reported by participants as another important cause of poor yields. Other factors listed to have contributed to low crop yield experienced by NAADS farmers were poor farm management practices—especiallly the management exotic crops, poultry and livestock because of the lack of labour, technical and financial resources needed to manage the enterprises. (Okoboi et al. 2011).

Sebaggala and Matovu, 2020 found that access to extension services has a negative and statistically significant effect on farmer productivity after controlling for various household characteristics. However, from existing literature, access to agricultural extension services is expected to have a positive effect on farm productivity. Using the probit-2SLS IV approach to generate the endogenous treatment results, they found that the extension access variable becomes positive, although not statistically significant showing that once endogenous selection bias is accounted for the impact of agricultural extension access on farm productivity becomes insignificant. It should be noted that selection and endogeneity problems can distort the actual impact of extension contact, hence the need to account for these bias issues. Justifications given for the insignificant effect of access to agricultural extension services gotten from their IV results was that access to extension services is not sufficient enough to translate into increased productivity. And that the quality of extension services matters more for farmer productivity, rather than the frequency of extension visits (Ragasa et al., 2012, Okoboi et al., 2013).

2.3 Empirical Reviews

Okoboi et al. 2012 estimated use of improved inputs and its effect on maize yield and profit using Uganda household survey data of 2005/06. Graphical result was used to check the difference in yield of adopters and non-adopters. Descriptive statistics is not enough to estimate effect of input. Descriptive statistic Will be appropiate when describing a set of data for which you have the entire set (that is, the full population of data). While Inferential statistics are used when you are making inferences about a population using the information in a sample (subset of the population). The appropriate approach for the data used by Okoboi et al. 2012 is inferential statistics as the data is a sample of the entire farmer population. They further estimate production function by using continuous variables for the agricultural input use (Price of fertilizer, seed, herbicides/fungicides) and assume the participation in NAADS to be exogenous, whereas participation is determined by age, gender and level disabilities of farmer (Agole, et al., 2021) . This can possibly cause the estimate to bias.

In 2013 Okoboi et al. estimate the impact of NAADS on household production and welfare in Uganda using Difference in Difference (DID) method based on Propensity score match with 2005/6 and 2009/10 Uganda Panel Survey and qualitative data from focus group discussion. This method compares before and after among a treated and control group. In other to use DID for effect estimation there must be a baseline data of the household before the intervention, so as to make comparison for before and after possible. For Uganda the impact evaluation of NAADS was conceived at the program design stage but baseline data was not collected to provide information on recipient backgrounds and production outcome before the Intervention. To control for this Okoboi et al.,2013 used propensity score matching to generate closely matching comparison of non-NAADS and NAADS participant. The propensity score matching is applied when it is possible to create matched data for treatment and non-treatment group to which difference in differences method was applied. PSM select programme participants and non-participants who are similar in terms of observable characteristics that are expected to affect participation in the programme and also the effect of participation.

Probit 2SLS has been considered as a better alternative to propensity score matching because it helps in overcoming the methodological challenges associated with endogenous selection (Sebaggala & Matovu, 2020). It is therefore appropriate to use this method to further estimate the impact of programme on household production.

In the year 2020 Sebaggala and Matovu estimated the effects of Agricultural extension services on farm productivity in Uganda using probit 2-stage least squares(2SLS) using ATAAS 2013 baseline survey covering 112 districts in Uganda. They controlled for input use, (Organic fertilizers and inorganic fertilizers), farm characteristics and household characteristics. Access to extension services was treated as endogenous variable and member of farmers group was used as instrument. But use of organic fertilizer and inorganic fertilizer which are endogenous variables were treated as exogenous.

The empirical literature on productivity effects of agricultural practices is not conclusive as researchers found mixed result (Benin et al., 2007:2011, Okoboi et al.,2012, Sebaggala & Matovu, 2020). The mixed result on yield effect is a consequence of how the methodological issues of endogeneity, heterogeneity and measurement of yield variable are addressed. Different studies had used OLS and IV approaches, Propensity Score Matching, Quantile regression, Difference in Difference Analysis. Evidence has showed that the use of OLS fails to account for heterogeneity in the effect of input use and extension services on productivity as well as biased introduced due to the endogeneity of input use and extension service. Instrumental variable approach is mainly used to address this bias but also has difficulty in identifying heterogenous treatment (Sebaggala & Matovu, 2020).

Under the IV approach, different estimation model has been designed to evaluate impact. These include direct 2SLS, IV probit and probit-2SLS. The IV probit can be used when the endogenous variable is continuous, the direct 2SLS is designed to estimate linear regression (Akotey,2015). This paper adopted probit 2SLS approach which fits binary and endogenous variable to estimate the impact of Agricultural practices on household production. MVprobit was first used to estimate the agricultural practices to derive the predicted probability. Second, the predicted probability was used as instrument to estimate the 2SLS. This approach was said to provide consistent and more efficient estimate compare to the direct-2SLS (Cerulli, 2012; Akotey,2015).

In conclusion, it should be noted that though numerous researchers have acknowledged that mixed results of the impact of agricultural practices on farming outcomes are because of endogeneity and selection bias and that these problems can be solved through the use of instrumental variable, few studies have been conducted. Therefore, the main contribution of this study is evaluating the impact of agricultural practices employed on farm productivity while controlling for selection and endogenous bias. And compare to Sebaggala& Matovu, 2020 that used probit 2SLS to estimate impact of extension on productivity this paper includes takes into effect endogeneity of other agricultural practices like use of improved seed, organic fertilizer, inorganic fertilizer and pesticide.

3.0 METHODOLOGY

3.1 Study site

Uganda is a land locked country in East-Central Africa with an area of 241,555 square kilometres(sq.km), 37,460 sq. km of this is open water, 7,621 sq. Km is wetland cover and the remaining 196,237 sq. km is land. Over time, the amount of cultivated land increases from 105,308 sq. km in 2015 to 106,662 sq. km in 2017. Uganda has annual population growth, of 3.03 percent with 174 persons per sq.km. Uganda has a very young population structure, 56.7% under 18 according to the 2014 census. The majority of the working population are engaged in agriculture, the agricultural industry making for 72 percent of the population's employment (UBOS, 2020).

Agriculture is the major source livelihoods for most rural households in Uganda. It is an important drive for the overall economic growth and possibly the single most important pathway out of poverty in the rural settlement. The most important food crops are maize, Irish potato, cassava, bananas/plantain, groundnuts and sorghum. Their main cash crop are tea, coffee, tobacco, cocoa, sugarcane, cotton and horticulture.

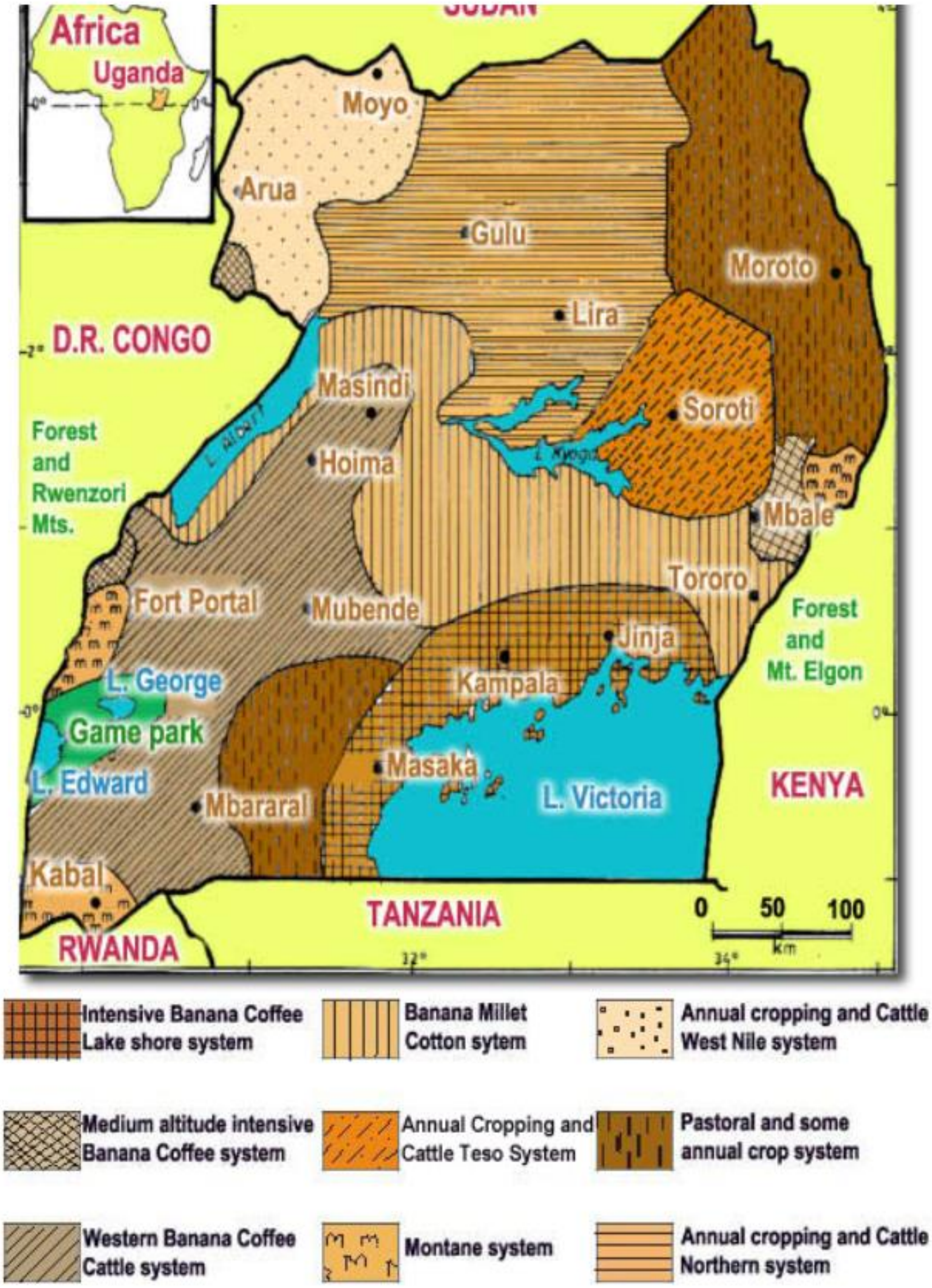

Figure 2: map of the Farming Systems in Uganda. (Retrieve from FAO,2015)

3.2 Data Description:

This study employs 2018/19 Uganda National Panel Survey (UNPS) that was conducted using survey solutions in March 2018 – February 2019 as part of the World Bank Living Standard Measurement Survey-Integrated Surveys on Agriculture (LSMS-ISA) project. The UNPS is carried out over a twelve-month period on a nationally representative sample of households. The survey is conducted in two visits in order to better capture agricultural outcomes associated with the two cropping seasons of the country. The UNPS therefore interviews each household twice in a year, in visits approximately six months apart. It thus covers the period between January and June. The second agricultural season is generally the period between July and December. It should be noted that seasons are directly related to rains and only indirectly related to the growing cycle of crops. For this analysis 2018/19 second visit data was used.

3.3 Model Specification

3.3.1 Multivariate Probit Model

A multivariate probit (MVP) model was used to capture decision process of farmers in the adoption of agricultural technology by small holder farmers. Multivariate probit model had been seen by econometricians as a generalization of probit model used to estimate several correlated binary outcomes simultaneously (H.Greene, 2002).

In general, multivariate model extends to more than two outcome variables just by adding equations. The model facilitates understanding the interconnectedness of different agricultural technologies by jointly modelling the effects of a set of covariates on each of the improved agricultural technologies , estimate set of binary probit models and allowing for potential correlation between unobserved disturbances. If correlation is positive then the technologies are complementary while negative correlation between different practices means substitutability. Positive correlation may also occur in the presence of unobserved farmer-specific characteristics affecting farmers decision but not captured by measurable proxies. The use of Univariate multinomial logit and probit will neglect the possible correlations of error terms of the adoption equations and this may result in bias estimate (William,2008; Kassie, et.al. 2013; Ahmed,2015; Donkoh et. al. 2019)

Technology Adoption can be modelled following random utility formulation. Consider the j^{th} household (j=1 ,…, N) confronted with a decision to adopt or not adopt productivity enhancing technologies on plot p (p=1,…, P) over a specified period of time. With utility U_t representing farmers benefit from traditional production system and U_k represent farmers benefit of adopting the k^{th} productivity enhancing technology and participation in extension services: (K=S, I, O, P, E) representing improved seed(S), inorganic fertilizer (I), Organic fertilizer(O), pesticide(P), and Extension service(E). The farmer chooses to adopt kth technology on plot p if:

$$D_{jpk}=U_k-U_t > 0; \text{ Where } D_{jpk} \text{ is the net benefit} \qquad (1)$$

The net benefit that farmers gain from k^{th} technology on plot p is a latent variable determined by observed and unobserved characteristics:

$$D_{jpk} = X'_{jpk}\beta_k + U_{jp} \qquad ((K=S, I, O, P, E) \qquad (2)$$

Where X_{jp}= household characteristics, institutional and plot characteristics

U_{jp}= unobserved characteristics

K= type of technology available

β_k = vector of parameter to be estimated

The observed binary outcome is given as:

$$D_{jpk} = \left\{ \begin{matrix} 1 \; if \; D^*_{jpk}>0 \\ 0 \; otherwise \end{matrix} where \; k = S, I, O, P, E \right\} \qquad (3)$$

In the MVP model, the error terms jointly follow a multivariate normal distribution with zero conditional mean and variance normalized to unity. Symmetric covariance matrix Ω is given by:

$$\Omega=\left\{ \begin{matrix} 1 & SI & SO & SP & SE \\ SI & 1 & IO & IP & IE \\ SO & IO & 1 & OP & OE \\ SP & IP & OP & 1 & EP \\ SE & IE & OE & EP & 1 \end{matrix} \right\}$$

The off-diagonal elements in the covariance matrix represent the unobserved correlation between the error components of the different agricultural technologies and participation in Extension services (NAAD).

Based on empirical work and economic theory, variables hypothesized to explain adoption decision and resulting yield increase are summarized under three major category (1) household characteristics, (2) institutional and (3) plot characteristics

3.3.2 Probit 2 Stage Least Squares

Yield as a measure of agricultural productivity refers to the output that is produced with given level of inputs and farm area. Productivity is an important variable in determining agricultural policy because variability in yield increases risk and makes decision process very important for farmers.

Taking yield impact as key indicator of adaptive capacity, we move to analysis of the relationship between farm practice selection to crop outcomes. The estimating equation for yield is given by equation 4.

$$Y_j = X`_j\beta + \delta D_j + \varepsilon_j \quad (4)$$

Y_j is assumed as outcome variable, D_j is the adoption dummy variable, $X`_j$ other explanatory variable and ε_j is the error term. Estimating outcome this way might generate biased estimates because it assumes that agricultural practice decision is exogenously determined while it is endogenous as describe in the determinant of adoption model.

In other to account for multiple endogeneity problems in the model, probit 2SLS (stage least squares) approach is employed as propose by Cerulli, 2011.First mvprobit model is estimated for all the agricultural practices on exogenous factors and instrument (membership of farmer group, livestock, age, age square, asset value,education, urban) to derive predicted probabilities as instrument of agricultural practices to estimate the 2SLS model. According to Cerulli 2011 and Akotey, 2015, this approach is known to yield consistent estimate and to be more consistent than direct -2SLS.

This empirical approach is considered as a better alternative to propensity score matching as it helps in overcoming the methodological challenges associated with endogenous selection (Sebaggala & Matovu, 2020).

The consistency of this method depends on the validity of instruments to identify the adoption equations. For the instrument to be valid, it must be correlated with the endogenous variables (use of agricultural practices) and be uncorrelated with unobserved factors that may affect yield.

The first stage of the model, which is mvprobit model has already been estimated in the first objective. The fitted value of this estimate Will be extracted to run the second stage of the regression estimate.

3.4 Description of Variables used

The dependent variable is the different agricultural practices employed by farmers such as making use of improved seed, inorganic fertilizer, organic fertilizer, pesticide and participation in National Agriculture Advisory service (NAAD), taking value of 1 if adopted and 0 otherwise.

The independent variables were divided into three categories: (1) Farm Household Characteristics (2) Farmland Characteristics (3) Economic and social capital

3.4.1 Farm Household Characteristics

These Include age, gender, education level of the household head and household size. The effect of age on adoption decision can either be negative or positive. It is believed that with age farmers gain more knowledge and are better to exploit new innovations, also there is a believe that older farmers are thought to be less open to change and therefore reluctant to change from their aged practices to new ones (Marenya & C.B.Barrett, 2007)

Younger farmers are believed to be more flexible and interested in trying new things and are more conversant with new communication technologies which are used to disseminate agricultural related information, but they have little experience compared to older farmers. Their relative lack of experience implies that there is lower opportunity cost in learning new technologies. Therefore, some researchers argue younger farmers are more likely to adopt new technologies and that they might be less patient or at a point in their life where they cannot afford to experiment with new technology (Aker, 2011)

Bokusheva et al. (2012), Ghimire and Huang (2015) find that household with old heads engage less in technology adoption. Usman et al., (2020) find age to have negative effect on adoption. Langyintuo and Mungoma (2008) find that older farmers in Zambia are more likely to adopt improved maize varieties. In general, there is no empirical clear effect of effect of age on adoption as it differs by location and crop (Bokusheva, et al., 2012; Ghimire & Huang.,2015; Langyintuo & Mungoma, 2008).

The role of education as a boost for agricultural technology adoption is broadly discussed in literature. Modern technology is complex and requires skills that is different from the traditional ways of farming. Educated farmers are believed to have better way to process information and convert it into practices. Some of the adoption study reviewed find a positive association between education levels and adoption. Kassie and Shiferaw (2012) find that spouse education might be important in making decisions about multiple sustainable agricultural practices within the family in Ethiopia. Usman et al., (2020) find education to have a negative impact on adoption of Sustainable agricultural practices.

Household size is used as proxy for labour used. Household size is more important if the technology to be adopted require physical labour such as integrated natural resources management (Marenya and Barrett 2007). While technology such as seed adoption that requires less labor has no correlation with household size (Ghimire and Huang 2015).

3.4.2 Economic and social capital

Economic capital consists of land ownership, Livestock ownership and household endowments (measured as sum of all asset value owned by each household). Where social capital includes membership of a farmer group. Rich household are likely to invest in capital intensive technology and be able to purchase input such as fertilizer, pesticide and improved seed. Farmers who rent or lease their farm plot might be reluctant to invest in input purchase as they feel threatened by contract termination and eviction (Kurgat, et al., 2018). Household that owns livestock can gather manure as a side product to be used in crop production and also use the livestock as draft power (Kassie M. , Jaleta, Shiferaw, Mmbando, & Mekuria, 2013).

Farmers' group ease access to information as they share information about new technology amidst themselves and learn from each other even with no contact with extension agent. It enables farmers to have access to inputs on schedule and overcome credit constraint. It also decreases transaction cost, increase farmers' bargaining power and assist farmers get higher revenue when they market their product (Kassie M. , Jaleta, Shiferaw, Mmbando, & Mekuria, 2013).

3.4.3 Farmland characteristics

These includes total area planted (farm size) and type of crop stand on the plot (cropping system). Farm size is very important in adoption decision because some technologies are scale dependent. Many literatures have reported a positive relationship between farm size and agricultural technology adoption while some found no effect (Uaiene et al.,2009; Mulwa et al., 2017; Udimal et al., 2018; Kurgat et al., 2018). Farmers with large size can afford to use portion of their plot to try new technology compare to small farm size farmers (Uaiene, Arndt, & Masters, 2009).

Farmers practice mixed cropping most times to reduce risk of crop failure. Crop react to shock differently, some are drought tolerant, some grow well on poor, while some are easily affected by climate change. Most of these farmers are risk averse, so they might be reluctant to adopting new technology with fear of additional cost and with no certainty of success.

To examine impact on yield, agricultural practices adopted and other farmland characteristics were used for the analysis. Yield was got by taking natural logarithm of quantity harvested measured in kilogram given by the farmers.

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

Definitions and summary statistics of the variables used in the analysis are given in Table 1. Five Agricultural practices was considered: Improved seed, Inorganic fertilizer, Organic fertilizer, Pesticide and Participation in NAADS.

Table 1:Definition of variables and Descriptive statistics

Variables	Description	Category	Mean	SD
Dependent variable				
Seed	Type of seed used by household (1=improved seed 0=traditional seed)	Binary	0.07	0.26
Inorganic fertilizer	Use of any inorganic fertilizer on parcels (1=yes 0=No)	Binary	0.02	0.14
Organic fertilizer	Use of any organic fertilizer on parcel (1=yes 0=No)	Binary	0.03	0.17
Pesticide	Use of any pesticide on parcel (1=yes 0=No)	Binary	0.04	0.20
log Yield	Logarithm of how much harvest during the second cropping season in kg	Continuous	5.58	0.88
Participate in NAAD	If household participate in training organized by National Agriculture Advisory service (1=yes 0=No)	Binary	0.05	0.22
Independent variable				
Age	Age in years	Continuous	48.29	14.87
Gender	Gender of respondent (1=male 0=female)	Binary	0.70	0.46
Urban	If household lives in urban or rural area (1=urban 0=rural)	Binary	0.123	0.33
Crop system	1=mixed cropping 0=pure stand	Binary	0.64	0.48
Log area farmed	Total area planted(acres)	Continuous	-0.60	0.83
Farmers group	Household member of farmer’s group (1=yes, 0=No)	Binary	0.32	0.47
Education	1=had 6years of formal education	Binary	0.72	0.45

Landown	Parcel (1=owned 0=accessed through land use)	Binary	0.91	0.28
Hhsize	Household size	Continuous	5.52	2.58
Logassetvalue	Total value of asset owned by household (local currency)	Continuous	14.59	1.64

The adoption rates of the agricultural practices considered is extremely low. All the inputs were scarcely applied :7% of the farmers adopted improved seed, 2% adopted Inorganic fertilizer, 3% adopted organic fertilizer, 4% used pesticide and only 5% of the household participated in NAADs. This clearly buttress the common view of low rates of agricultural technology adoption in Uganda and other developing countries. The average age of the household head is 48 years indicating that on average farm households are still in their active farming years. 70% of the household head are male suggesting greater male roles in the farming population. On the other hand, the average household size is approximately 6 indicating large family settings. Large household size is a feature of most agricultural settings in developing countries signifying the possibilities of use of family labour. Depending on the type of agricultural technologies, household size has been reported as a determinant that is considered in the household's decision to adopt.

Household's statistics further revealed that 72% of household's head had at least 6 years of formal education, suggesting that a large number of the household's head are educated and could have easy knowledge of farm practices and uptake of technological information.

Also, 91% of the households' head are tenure secured, probably because of ease in transferring rights that is common in most Africa countries. Studies has shown that secure land tenure is an important factor that affect agricultural technology utilization by smallholder farmers as it provides incentives for investment to increase the productivity of the land. (Kyomugisha, 2008). From the descriptive analysis, asset value represents non-farm asset such as household appliances, generators, motorcycle, non-agricultural land, mobile phone, radio, motor vehicle, etc., in this case, households with higher asset value are indicative of better welfare status and thus have ability to purchase expensive agricultural inputs.

64% of the farmers are involved in mixed cropping. Beans, maize and cassava cropping is the most prominent among Uganda farmers due to the fact that they are the major staple crop. Most farmers do this to ensure food availability throughout the year (Mukadasi, 2018).Also , mixed cropping is practiced to reduce loss due to pest infestation as most pests are crop specific.

From the analysis 32% of the farmers are member of farmers group, 12% lives in Urban settlement and the average farmsize is 0.7 acre.

4.2 Determinants of adoption – MVP results

The maximum likelihood estimates of the MVP model of agricultural practices adopted are presented in Table 3. It shows the driving forces behind farmers' decisions to adopt agricultural technology and participation in National Agriculture Advisory service. Where the dependent variable takes the value of 1 if the farmer uses specific practices or inputs on a given plot and 0 otherwise. The Wald test of the hypothesis that all regression coefficients in each equation are jointly equal to zero is rejected. Also, the likelihood ratio test of the null hypothesis that the error terms across equations are not correlated is also rejected as reported in Table 2

Table 2: Correlation coefficient of mvprobit

	Seed	Inorganic Fert	organic Fert	Pesticide	participateNAAD
Seed	1	0.423***	0.133	0.209**	-0.322***
Inorganic Fert		1	0.006	0.528***	-0.083
Organic Fert			1	0.211*	0.134
Pesticide				1	0.095
ParticipateNAAD					1

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0: chi2(10) = 52.711 Prob > chi2 = 0.0000

The table shows that the estimated coefficient is statistically different from zero. Five out of ten correlation coefficients of pairwise correlation were significantly correlated, four are positive showing complementarity while one is negative showing substitutability. This suggests that the propensity of using a practice is conditioned by whether other practices has been used or not. This Justifies the use of MVP in comparison to Univariate probit. The sign of the coefficient supports the notion of interdependency among the agricultural practices. relationship between improved seed and Inorganic fertilizer, Improved seed and pesticide is positive. The highest amidst them all is the correlation between inorganic fertilizer and pesticide (53.9%). This shows that Uganda farmers still practice the use of chemical fertilizer and pesticide for crop intensification. Chemical fertilizer and pesticides are important tools for food security but their adverse effect cannot be overlooked if sustainable agriculture is the focus.

There is negative correlation between participation in NAADS and use of improved seed. Table 2 further revealed that participation in NAADS does not translate into technology adoption as there is no significant correlation between technology adoption and participation in NAADS, though the program was implemented to improve technology adoption. Earlier study conducted by Okoboi et al. 2013 on influence of NAADS on technology adoption shows no clear evidence of participation in NAAD on use of improved technologies.

Table 3: Determinant of adoption. Multivariate Probit Result

	Improved Seed	**Inorganic fertilizer**	**Organic fertilizer**	**Pesticide**	**Participate NAAD**
Cons	-1.710	-3.643***	-4.08***	-2.679**	-6.079***
	(0.823)	(1.290)	(1.206)	(0.998)	(1.12)
Age	0.026	-0.019	0.024	-0.048	0.060*
	(0.029)	(0.039)	(0.037)	(0.032)	(0.036)
Agesq	-0.0003	0.0001	-0.0002	0.0004	-0.0005
	(0.0003)	(0.0004)	(0.0003)	(0.0003)	(0.0003)
Gender	0.294*	0.537*	-0.236	-0.153	0.524**
	(0.153)	(0.302)	(0.185)	(0.177)	(0.210)
Cropsystem	0.217	-0.293	-0.421**	-0.724***	0.041
	(0.134)	(0.194)	(0.172)	(0.160)	(0.157)
Logreafarmed	0.233***	-0.061	-0.086	0.087	-0.077
	(0.080)	(0.118)	(0.104)	(0.091)	(0.095)
Farmer’s group	0.237*	-0.297	0.069	-0.498**	0.892***
	(0.126)	(0.230)	(0.182)	(0.197)	(0.154)
Urban	0.153	0.142	-0.540	0.136	-0.203
	(0.182)	(0.260)	(0.330)	(0.216)	(0.228)
Education	0.128	0.188	-0.074	0.009	0.239
	(0.146)	(0.246)	(0.190)	(0.178)	(0.185)
Hhsize	-0.016	-0.031	-0.062*	0.023	-0.022
	(0.025)	(0.042)	(0.037)	(0.032)	(0.030)
Lvstck	0.149	-0.246	-0.033	-0.272	-0.015
	(0.130)	(0.212)	(0.181)	(0.168)	(0.158)
Landown	-0.094	0.020	-0.184	-0.402*	-0.230
	(0.213)	(0.354)	(0.299)	(0.243)	(0.262)
Logasset_value	-0.037	0.137**	0.168***	0.214***	0.144***
	(0.040)	(0.067)	(0.058)	(0.056)	(0.048)
Observations	1019	1019	1019	1019	1019

Log likelihood	-757.6238
Wald chi2(60)	162.81
Prob > chi2	0.000

Note: *p<0.1; **p<0.05; ***p<0.01. Standard error in parentheses

Prior to estimating the adoption models, the independent variables were scrutinized for possible strong correlations among them and variables that are correlated are excluded from the analysis.

The effect of the covariates used to explain adoption are heterogenous and depend on the type of agricultural practices. With regard to household characteristics Male headed household are more likely to adopt improved seed, Inorganic fertilizer and participate in NAAD. We can attribute this to resource endowment characteristics and higher labour availability of male-headed household. Similar to Mulwa et al. (2017) that found out that the availability of male family labour determines the adoption of soil and water conservation measures in Malawi and also Ragasa et al (2013) that found out that gender of the household head significantly affects adaptation through soil and water conservation measure, due to more labour availability and asset endowment of household head.

The education level of the household head has no significant in explaining any of the agricultural practices considered, however in the case of pesticide Lamichhnae, et al., 2015 explained that crop pest problems in the sub-Saharan Africa are expected to worsen with future climate change impacts as most farmers in Uganda lack options for pest control as new and emerging pest are destroying their crop. Most educated farmers used pesticide based on lack of options rather than lack of awareness (Luna,2020).

The coefficient of household size variable is only significant($p<0.1$) in driving the adoption of only organic fertilizer. This can be explained by the capital-intensive nature of organic fertilizer. As use of organic fertilizer is labour saving, it is mostly attractive to small sized households or farmers with small number of adult members (Ashfaw, 2014).

Age and gender have positive effect on participation in NAAD meaning increase in age increase the chances of participation. Though the program is targeted to support households headed by women, young people and people living with disabilities (PLWDs), it appears that non-youth and male headed household are benefitting from the program. Okoboi et.al., (2013) reported that the gap between youth and non-youth households head participating in the program increased by 13 percent in 2009/10 compare to 2005/6 when it was just 1.8 percent and the gap between female headed household and male headed household in 2009/10 increased to 7.2 percent from 0.5 percent in 2005/6.

Information gathered during Focus group discussion conducted in September and October 2012 to examine factor influencing participation in NAADs reveal that the women that participated are married and are often those whose husband were in NAAD administrative or in leadership of farmers groups. Also, youth are belittled and are often discriminated by older persons. Information about the program the Programme is done through door-to-door communication by village leaders who only pass the information to people they desire to participate (Okoboi, Kuteesa, & Barungi, 2013).

Being member of a farmer group has positive effect on participation in NAAD. This is because the program has based its implementation strategy on farmers group concept. To participate in the program, farmers have to join existing groups or form new group within the village and then combine to form the village farmer forum. Farmer group also significantly determined adoption of improved seed and pesticide.

Mixed cropping has negative effect on adoption of inorganic fertilizer, organic fertilizer and use of pesticide but only significant in explaining organic fertilizer and pesticide use. So, Farmers practicing Mixed cropping are less likely to adopt organic fertilizer this might be because legumes are part of the crop on the plot. This crop re-enforces the nitrogen fixing potential of the farming system. Also, most pest are crop specific, planting different crop on the plot limit their destructive effect and this ensures that farmers are able to harvest at least one of the crops planted if others are been destroyed by pest. Fermont and Benson (2011) reported that 70 percent and above of farmers in Uganda practice intercropping and this was done to spread risk by diversifying production and increasing their total output of individual fields.

From the result, estimate of land ownership was negative and significant ($p<0.1$) in driving the adoption of pesticide. Landownership has been generally hypothesized to encourages agricultural technology adoption, while the lack of land ownership discourages it but this estimate shows otherwise in the case of pesticide. This might be because farmers are more concern in preserving their land owned than rented one. Massive use of pesticide reduces land yield over time and reduces the value of parcel (Hillocks, 2012). This is contrary to the findings of Matteo Migheli (2017) that quantity of pesticides use increases as the share of cultivated land own increases.

Log of asset value significantly increases the decision to adopt inorganic fertilizer, organic fertilizer, pesticide and participation in NAADS. Implying the role of wealth in driving adoption of input. Wealthier household adopt practices that need more initial capital.

The location of the farmer either urban or rural and livestock ownership has no significant in explaining the adoption of any of the agricultural practices examined.

Three of the observable characteristics use in studying adoption influence participation in NAADS as well as adoption of agricultural technology: being a member farmers group positively influence use of improved seed and participation in NAADS but negatively influence use of pesticide. Gender has positive influence on adoption of improved seed, inorganic fertilizer and participation in NAADS. Log asset value has positive significant on the adoption of inorganic fertilizer, organic fertilizer, pesticide and participation in NAADS.

The Adoption estimate results further revealed that farm land characteristics have no influence on participation in NAADS but that the program is only influenced by household and social capital characteristics (Age, gender, farmers group and asset value).

Most of the covariates used in the adoption analysis follows logical pattern with most studies conducted on adoption in east Africa and most sub Saharan Africa countries

4.3 Impact on productivity- OLS results and Probit 2SLS result

Table 4: impact of agricultural practices adoption on yield

	Dependent Variable: Log Yield	
	OLS	**Probit 2SLS**
Improved seed	0.052	
	(0.106)	
Inorganic fert	-0.077	
	(0.202)	
Organic fert	0.102	
	(0.161)	
Pesticide	-0.074	
	(0.144)	
ParticipateNAADS	0.167	
	(0.124)	
Fitted_improved seed		-0.019
		(0.172)
Fitted_inorganicfert		0.244***
		(0.121)
Fitted organic Fert		0.126
		(0.110)
Fitted pesticide		-0.010
		(0.122)
Fitted_participateNAAD		0.107
		(0.069)
Landown	0.059	0.069
	(0.096	(0.115)
Logareafarmed	0.184***	0.206***
	(0.033)	(0.062)
Crop system	0.224***	0.363***
	(0.057)	(0.078)

Constant	5.479***	6.365***
	(0.104)	(0.308)
Observations	1,021	1,019
R2	0.047	0.071
Adjusted R2	0.039	0.064
Residual Std. Error	0.861(df=1012)	0.850(df=1010)
F Statistic	6.172*** (df = 8; 1012)	9.640*** (df = 8; 1010)

Note: *p<0.1; **p<0.05; ***p<0.01. Standard error in parentheses

Table 5 reports results for OLS and Probit 2SLS estimation for the impact of input use and NAAD on crop productivity. One approach to investigate the effect of input use is estimating an OLS model of productivity without controlling for any potential endogeneity problems and with a dummy variable equal to 1 if the farmer decided to use the practices on a given plot, 0 if otherwise. The OLS results would lead us to conclude that there are no significant observable differences in terms of agricultural outputs between users and non-users as the estimates for all the agricultural practices are not significant. This approach, however, assumes that the uses of these agricultural practices are exogenously determined in the production which is not true. Therefore, the estimation via OLS would yield biased and inconsistent estimates.

The impact estimates presented further on use of Probit 2SLS.The first stage of the regression has already been estimated with the mvprobit model used to explain adoption decision. The fitted value of the agricultural practices generated from the mvprobit was used for the yield equation. As expected, the use of inorganic fertilizer has positive impact on crop yield. However, the use of organic fertilizer and participation in NAAD have positive coefficient but not statistically significant. Benin et al. (2007) in their evaluation of impact of NAAD program observed that, there was no significant changes in yield between NAADS and non-NAADS households for most crops. Okoboi et al. (2012) found mixed results for the impact of NAADS on productivity. Kwapong & Nkonya (2015) reported that political interference is one of the problems hindering NAADS from meeting it objectives. The use of improved seed and pesticide have negative non-significant effect on yield. IMF reports 2020 shows that (fertilizer, improved seeds, protection against erosion and pesticides improve crop yield in Rwanda and Ethiopia but not Uganda, possibly associated with lack of use there.

The result of the mvprobit analysis revealed that participation in NAADS does not influence technology adoption, as there is no significant correlation in the unobservable determinant of participation in NAADS and the agricultural technologies considered in the analysis, indicating that the program is not meeting its objective. Access to information and training had been highlighted by studies to have positive effect on adoption decision. However, training and services provided by NAADS programme fall short of this expectation. This further explains why participation in the programme does not affect yield in the probit 2SLS estimation though it has positive coefficient.

Participation In NAAD or any extension service is not sufficient enough to translate into increased productivity (Sebaggala & Matovu, 2020).Also, it might be that the service provider i.e., the extension agents are not efficient in their delivery. Evidence from Uganda and Ethiopia shows that the quality of the extension services matter more for productivity than the frequency of extension visits (Ragasa et al.,2012). It has been noted that beyond the influence of visits or advice by extension services there is no direct influence of the programme on productivity. Most of the extension services in Uganda focuses on input delivering and urging farmers to adopt agricultural technology and seek credit facilities (Sebaggala & Matovu, 2020). Okoboi et al.,(2013) reported that though NAADS has a great impact on access to extension service in Uganda, the quality of extension services in still poor particularly the incompetence of the extension providers.

Other covariates that significantly increases yield are area of farm planted and the type of crop system practiced. The positive coefficient of area planted implies that increase in area planted is associated with high output per acre, but land size had been hypothesized to have inverse relationship with productivity. This had been confirmed by numerous studies that smaller farms are more productive than large ones (Betz,2011; Ladvenicova & MIklovicova 2015; Julien et al.,2019). The positive relationship observed in this estimate might be because only smallholder farmers are considered. The average farm size of farmers used for this analysis is 0.77acres so it is possible that the inverse relationship will hold if increases were in larger percentage. Sebaggala & Matovu, 2020 reported that the square of land has a positive impact on productivity i.e.

agricultural productivity first reduces with land size and then increases after a given threshold. Below the threshold this threshold small farmers are more productive and beyond the threshold productivity increases with land size. Rada & Fuglie (2019) states that the relationship between farm size and productivity evolves with the stage of economic development.

Use of pesticide and improved seed has negative but not significant relationship on productivity. This might be because farmers in Uganda are impacted by new and emerging pests which pose serious problem on productivity. Farmers applied pesticide to crop based on the known pest that had been affecting their crop from previous planting season or crop specific pest. So, it is difficult for them to control for the pest they are not aware of .Study conducted by Andersson & Isgren (2021) on Farmers in Paya Uganda states that crop pest problem has intensified over the past 15-20 years and connected this to changing climatic condition and increase in extreme weather events. Also, that crops are becoming weaker and are susceptible to pest damage and that most farmers lack knowledge on the specific type of pests that attack their crop.

Organic fertilizer has positive but not significant this can be based on the quantity used. Soil nutrient depletion rate in Uganda is high, the country is classified as one of the highest in terms of soil depletion.Uganda has one of the highest soil nutrient depletion rates in the world. The soil has very low nutrient holding capacity, they are deeply weathered and very old. The annual depletion rate is 87kg on average per hectare and to replenish the soil 3-5mT of manuare have to be added annually (Godfrey & Dickens, 2015). For highly depleted soil lime plus organic matter is describe as the best remedy. But most farmers have no idea on either to use organic or inorganic based on the soil problem.

5. CONCLUSION AND RECOMMENDATION

Most studies on agricultural practices adoption have shown that it can play an important role in alleviating low soil fertility and low yield but basically focus on understanding the determinants of adoption without analyzing their effects on productivity**.** This study contributes to empirical literatures by examining adoption of the agricultural practices and their impact on yield**.**

Multivariate probit model and probit 2SLS was used to explore the factor influencing the adoption of agricultural practices and their impact on productivity among small holder farmers in Uganda using 1021 observations from the second visit data of 2018/19 National Panel data. The results show that there exist some complementarities (e.g., improved seed and inorganic fertilizer, improved seed and pesticide, inorganic fertilizer and pesticide, organic fertilizer and pesticide) and substitutabilities (e.g., improved seed and participation in NAAD) among the agricultural practices. Therefore, readjustment of a policy on a given agricultural practices can have spillover effects on other technologies available. This suggests that the interdependence nature of agricultural innovations should be considered in designing effective strategies for the development and dissemination of agricultural technology in Uganda. For example, Policy to promote the use of improved seed should be formulated in a way that it will support the adoption of inorganic fertilizer, organic fertilizer and participation in NAAD as they are either complementary or supplementary.

The mvprobit estimation further shows the factor influencing farmers' adoption decision differ among agricultural practices. Age, gender, crop system, area farmed, farmer group, household size, land ownership and asset value play significant roles with differing signs across the practices. policymakers should take into consideration several farm characteristics, socio-economic characteristics and household factors to ensure that farmers can maximize the benefits of Agricultural technology.

The log of asset value is an important factor affecting farmer adoption decision as it have positive and significant relationship on use of inorganic fertilizer, organic fertilizer, pesticide and participation in NAADS. Policy that will positively influence the wealth capacity of smallholder farmer should be considered.

For NAADS in Uganda evidence has shown the target people for which the programme was made for get little or no benefit from the program. The programme administration should be review to ensure that the target group are also in position of power and by that be able to offer services to the people. The insignificant positive relationship of NAADS on yield shows that access to the current extension service does not translate to increase in yield reason based on the weakness of Uganda's extension service system argued by Benin et al. (2011) and Okoboi et al. (2013) that the quality of Uganda extension service is poor. So, for NAADS to achieve its aim in the aspect of extension the quality of the services provided should be of greatest importance.

On the impact of adoption on yield, the use of inorganic fertilizer is the only agricultural practices that influence yield, it is positive and significant. Other agricultural practices considered (improved seed, organic fertilizer, pesticide and participation in NAAD) have no effect on yield.

Future studies may be necessary to better draw conclusions on the effect of agricultural input use by farmer on productivity. It is important to evaluate whether the quantity of input use , soil type and other variables that can affect the efficiency of technology.

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AGRICULTURAL TECHNOLOGY ADOPTION, EXTENSION SERVICE, IMPACT ON PRODUCTIVITY: CASE STUDY OF SMALLHOLDER FARMERS IN UGANDA

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The study examines the determinants of agricultural practices adoption in Uganda and their effect on productivity, using a nationally representative data set of 1021 farming households, collected by the Ugandan Bureau of Statistics in 2018/2019. The agricultural practices analysed are improved seeds, inorganic fertilizer, organic fertilizer, pesticide and participation in National agricultural advisory service programme in Uganda.

Estimates from multivariate probit regression model shows the factor influencing farmers' adoption decision differ among agricultural practices. Age, gender, crop system, area farmed, farmer group, household size, land ownership and asset value play significant roles with differing signs across the practices and that there is interdependence among the agricultural practices considered. Probit 2SLS reveals that inorganic fertilizer has positive and significant effects on crop productivity. The use of organic fertilizer and participation in NAAD have positive coefficient but not statistically significant.Also, Pestcide and improved seed has negative and insignificant effect. Findings imply that the interdependence nature of agricultural innovations should be considered in designing effective strategies for the development and dissemination of agricultural technology in Uganda and that several farm characteristics, socio-economic characteristics and household factors to ensure that farmers can maximize the benefits of Agricultural technology be put into consideration.

Keywords Uganda, smallholder farmer, Multivariate probit, Probit 2SLS, Improved seed, Inorganic fertilizer, Organic fertilizer, Pesticide, Participation in NAADS.