Potential Drivers of Adoption of Agronomic Practices: A Case of Beans Farmers in Uganda

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This study aimed to identify the factors influencing the adoption of agronomic practices among bean farmers in Uganda, using secondary data from 1,908 farmers collected by the National Agricultural Research Organization (NARO). The analysis involved fitting multivariate probit and Poisson models to estimate the marginal effects of various determinants. The findings showed that 896 farmers adopted at least one agronomic practice, with mixed results in terms of direction and impact. Key positive determinants included marital status, education level, full-time farming, age, farming experience, farmer group membership, and credit access. Conversely, being male-headed, marital status, full-time farming, farm size, household size, and credit access were also identified as negative determinants. The study underscores the importance of socio-demographic and institutional factors in adopting agronomic practices and suggests integrating these insights into agricultural extension services. Further research is recommended to explore regional differences in adoption determinants across Uganda.

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I. BACKGROUND

Agriculture is a backbone of Uganda's economy, contributing to about 46% of the total export earnings (MAAIF, 2018). Agricultural agronomic practices refer to those best practices that advocate for efficient use of water, nutrients (fertilizer application), insecticides, herbicides, fungicides, and minimum tillage as one way of reducing environmental pollution from agricultural production (Valieva, 2010). It is widely recognized that farmers' access to information enhances their awareness of improved technologies and fosters the adoption of innovations (Koskei et al., 2013). Common beans *(Phaseolus vulgaris L.)* are the most common legume and the second most important source of dietary protein consumed globally (Ntatsi et al., 2020).

In sub-Saharan Africa (SSA), including Uganda, over 80% of the population relies on agriculture for their livelihoods (Kelil et al., 2020). However, the adoption of agronomic practices and new farming methods that could improve agricultural productivity remains low (Adjepong et al., 2019), despite their association with increased yields (Mulimbi et al., 2019). Unsustainable agronomic practices have led to declining agricultural yields, with 39% of Uganda's arable land being degraded and about 10% severely degraded (NEMA, 2016). While research has typically used a binary approach to identify factors associated with the adoption of agronomic practices Ahmad et al., (2021) & Akinola, (2017), there is still inadequate information on the use of these practices and their associated factors in Uganda. Thus, this study aims to investigate the socio-demographic and institutional factors influencing the use of agronomic practices in Uganda among beans farmers.

II. OBJECTIVES

i. To identify the socio-demographic factors associated with use of agronomic practices among beans farmers in Uganda

ii. To identify the institutional factors associated with use of agronomic practices among beans farmers in Uganda

III. METHODOLOGY

3.1 Data Source

This study utilized secondary cross-sectional data from an evaluation study by the National Agricultural Research Organization (NARO) on the impact of improved bean and maize technologies on livelihood and economic development. The study employed a cross-sectional research design with a mixed methods approach, incorporating both qualitative and quantitative data collection methods. The primary objective was to assess the impacts of improved NARO bean and maize varieties on food security, nutrition, and income at both farm household and national levels.

3.2 Target Population and Inclusion Criteria

The study targeted farmers who had adopted improved NARO bean and maize technologies and were directly involved with NARO and its partners in the development or dissemination of these technologies.   Out of the total sample size, 1,908 households (representing 83% of the sample) responded to the study. The actual sample size was influenced by budget constraints and the inclusion of many households initially considered non-participants but who were also adopters (Akwango-Aliau et al., 2022).

3.3 Analytical Methods

A multivariate Probit model will be employed to identify the determinants of the adoption of agronomic practices in Uganda, based on predictor variables selected during the exploratory phase. Additionally, a Poisson regression model will be used to determine the factors influencing the number of agronomic practices adopted by bean and maize farmers. The Poisson regression was chosen for its simplicity in predicting count data.

IV. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

4.1.1 Descriptive Analysis of the Adoption of the Agronomic Practices and the Factors that affect their Adoption among beans Farmers

Table 1 shows the percentage of bean farmers who adopted various agronomic practices. Out of a total of 896 bean farmers, 40.6% adopted crop rotation, 71% adopted row planting, 60.7% used fertilizer application, 33.4% adopted seed rate management, 70.1% practiced weed management, and 38.8% utilized other agronomic practices such as mulching, intercropping, relay cropping, minimum tillage, thinning, and staking. On average, bean farmers adopted about three agronomic practices.

The table also provides a descriptive analysis of various factors hypothesized to influence the adoption of agronomic practices among bean farmers. Among the 896 farmers, 73.8% were from male-headed households, while the remainder were from female-headed households. Regarding marital status, 7.3% of the household heads were single, 81.8% were married, and 10.9% were divorced or widowed. In terms of education, 4.8% of the household heads had no formal education, 48.4% had completed

Additionally, the average household size was seven members. In terms of group affiliation, about 79.5% of the bean farmers belonged to a farmer group, and approximately 73.7% had access to credit for crop production.

Table 1: Descriptive analysis of the adoption of the agronomic practices and the factors hypothesized to affect their adoption among beans farmers

Dependent variables					
Agronomic practice	**Obs**	**Mean**	**Std. dev**	**Min**	**Max**
Crop rotation (1=Yes 0=No)	896	0.406	0.491	0	1
Row planting (1=Yes 0=No)	896	0.710	0.454	0	1
Fertilizer application (1=Yes 0=No)	896	0.607	0.489	0	1
Seed rate (1=Yes 0=No)	896	0.334	0.472	0	1
Weed management (1=Yes 0=No)	896	0.701	0.458	0	1
Others (1=Yes 0=No)	896	0.388	0.488	0	1
Number of practices used	896	3.146	1.234	1	6
Independent variables					
Sex of the household head (1=Male 0=Female)	896	0.738	0.440	0	1
Marital status					
Single (1=Yes 0=No)	896	0.073	0.260	0	1
Married (1=Yes 0=No)	896	0.818	0.386	0	1
Divorced/ Widowed (1=Yes 0=No)	896	0.109	0.312	0	1
Education level of the household head					
No formal education (1=Yes 0=No)	896	0.048	0.214	0	1
Primary (1=Yes 0=No)	896	0.484	0.500	0	1
Secondary (1=Yes 0=No)	896	0.371	0.483	0	1
Tertiary/Higher education (1=Yes 0=No)	896	0.097	0.296	0	1
Household Main occupation (1=Full time farming 0=Part time farming)	896	0.801	0.399	0	1
Age of household head	896	46.888	11.988	23	82
Farm Size (ha)	896	4.873	5.206	0	70
Farming experience (years)	896	12.563	10.133	1	50
Household size	896	7.448	3.858	1	43
Member to farmers' group (1=Yes 0=No)	896	0.795	0.404	0	1
Access to credit (1=Yes 0=No)	896	0.737	0.441	0	1

Source: Author's calculation

4.1.2 Number of Agronomic Practices used by beans Farmers

Table 2 illustrates the distribution of the number of agronomic practices adopted by bean farmers. The results show that 7.9% of the farmers adopted one agronomic practice, 24% adopted two practices, 33% adopted three practices, 18.3% adopted four practices, 14.1% adopted five practices, and 2.7% adopted all six agronomic practices included in the study.

Table 2: Descriptive statistics for the number of agronomic practices adopted by the beans farmers

Number of practices adopted	Freq.	Percent
1	71	7.9
2	215	24.0
3	296	33.0
4	164	18.3
5	126	14.1
6	24	2.7
Total	896	100.00

Source: Author's calculation

4.1.3 Average Marginal Effects of the Multivariate Probit and the Poisson Estimates for beans Farmers on Adoption of Agronomic Practices

Table 3 presents the average marginal effects from the multivariate Probit and Poisson estimates regarding the adoption of agronomic practices by bean farmers. The following discussion focuses on covariates that significantly influenced the adoption of various agronomic practices, as shown in Table 8. The discussion is organized by covariate, as the effect of each independent variable on the adoption of agronomic practices is generally consistent across different practices. Below are the key factors that significantly affect the adoption of the various agronomic practices.

4.2 Sex of the Household Head

Results indicate being a male-headed compared to a female-head household on average decreases the likelihood of adoption of others by 11.8%. This is partly because men are involved in other income generating activities to provide for the family hence limiting factor to work on the farm as well as access to extension services. This is because women bear most of the household and farm responsibilities (Quisumbing, et al., 2014) and therefore men are not fully engaged in the farm activities. These findings are consistent with that of (Kassie, Zikhali, Manjur, & Edwards, 2009) who found out that male-headed household's probability of adopting the use of compost decreased and underscored the need to avoid generalizing the impact of gender on agronomic practice adoption, emphasizing that the impact of gender on adoption is practice-specific.

4.3 Marital Status

Being married compared to being single on average, increases the likelihood of adoption of crop rotation by 15.7%. This is because married couple households engage significantly in organized farming that include adoption of agronomic practices than other types of households. These findings concur with studies by (Tisdell, 2014) who reported that married farmer's work more hours than unmarried ones, working not only cash food crops but also on non-food cash crops and therefore easily adopt these agronomic practices.

Still, being widowed/divorced compared to being single on average decreases the likelihood of adoption of fertilizer application by 15.6% but increases the likelihood of adoption of crop rotation by 26.5%. This reduction in the probability of adoption of fertilizer application is partly due to the fact that fertilizer application requires more labor, hence increasing costs.

4.4 Educational level

Relating to education level, completing secondary compared to having no formal education on average increases the likelihood of adoption of fertilizer application by 17.3%. Also, completing tertiary/higher education compared to having no formal education on average increases the likelihood of adoption of row planting and seed rate by 17.3% and 18.3% respectively. This result simply shows the importance of education in raising the awareness of the farmer and increasing the farmer's chances of adopting important agronomic practices. Results are consistent with those of several other studies (Amsalu & Graaff, 2007) who found that educated farmers are able to process information and evaluate practices.

Table 3: Average Marginal Effects of the Multivariate Probit and the Poisson Estimates

Variable	dy/dx for multivariate probit model estimates						dy/dx for Poisson estimates
	Row planting	Fertilizer application	Weed management	Crop rotation	Seed rate	Others	Number of practices used
Sex ref (female) Male (1=Male 0=Female)	0.044 (0.008)	-0.084 (0.009)	0.075 (0.005)	0.082 (0.014)	0.060 (0.007)	-0.118** (0.014)	0.053 0.199)
Marital status ref (single) Married (1=Yes 0=No)	0.107 (0.019)	-0.002 (0)	-0.027 (0.003)	0.157** (0.027)	-0.047 (0.006)	0.064 (0.008)	0.263 (0.265)
Widowed/Divorced	0.089(0.015)	-0.156* (0.016)	0.106 (0.012)	0.265*** (0.045)	-.003 (0)	-0.076 (0.009)	0.204 (0.287)
Education level ref (No formal education) Primary (1=Yes 0=No)	0.108 (0.019)	0.026 (0.003)	0.068 (0.008)	-0.007 (0.001)	0.096 (0.012)	-0.039 (0.005)	0.242 (0.278)
Secondary (1=Yes 0=No)	0.063 (0.011)	0.173** (0.018)	0.015 (0.002)	0.065 (0.011)	0.114 (0.014)	0.060 (0.007)	0.489 (0.293)
Tertiary/Higher (1=Yes 0=No)	0.156* (0.027)	0.147 (0.015)	-0.09 (0.01)	0.110 (0.019)	0.183* (0.022)	-0.068 (0.008)	0.457 (0.338)
Main occupation (ref =Part time Agriculture) Full time Agriculture	0.094** (0.016)	0.044 (0.004)	-0.071 (0.008)	-0.086** (0.015)	0.031 (0.004)	-0.008 (0.001)	0.006 (0.156)
Age	0.001 (0)	0 (0)	-0.002 (0)	0.006*** (0.001)	0.002*** (0)	0.006 (0.001)	0.012** (0.006)
Size of farm land(ha)	-0.005 (0.001)	-0.009** (0.001)	-0.003 (0)	-0.003 (0.001)	0.002 (0)	-0.014*** (0.002)	-0.037** (0.015)
Farmer experience	0.064*** (0.011)	0 (0)	0.003* (0)	0.003* (0.001)	0 (0)	-0.001 (0)	0.01 (0.006)
Household Size	-0.006 (.001)	-0.007 (0.001)	0.004 (0)	-0.014*** (0.041)	-0.014*** (0.002)	-0.001 (0)	-0.036* (0.019)
Belonging to a Farmer group ref (No)	-0.026 (0.005)	-0.024 (0.002)	-0.024 (0.003)	0.244*** (0.004)	0.128*** (0.016)	0.151*** (0.018)	0.427** (0.150)

Yes (1=Yes 0=No)							
Access to credit ref (No) Yes (1=Yes 0=No)	-0.105 (0.018)	0.136** (0.014)	0.038 (0.004)	-0.024	-0.168** (0.021)	0.008 (0.001)	-0.051 (0.143)

4.5 Main occupation

With regards to main occupation, being a full-time farmer compared to being a part-time farmer increases the likelihood of adoption of row planting by 9.4% on average. However, being a full-time farmer compared to being a part-time farmer on average decreases the likelihood of adoption of weed management and crop rotation by 7.1% and 8.6% respectively. This is because being a full-time rather than a part-time farmer acts as a catalyst for continuation since agronomic practices require adequate expertise and an active presence in the farm. This finding is consistent with that of Bartolini et al. (2013), Morgan et al. (2015), and Pierpaoli et al. (2013). In addition, Teshome et al. (2016) found out that farmers' involvement in full time farming is positively related to maintaining agronomic practices. However, findings also show that being a full-time farmer compared to being a part-time farmer decreases the probability of adopting crop rotation and weed management. This finding contradicts with the finding of Teshome et al. (2016) who found full-time farming is positively related to maintaining agronomic practices.

4.6 Age

Furthermore, a unit increase in age of the household head increases the likelihood of adoption of crop rotation and others by 0.6% on average. Also, a unit increase in age of the household head increases the expected number of agronomic practices used by a farmer by 1.2%. This is because older bean farmers are more skilled and more experienced in adopting agronomic practices to maximize productivity. Results are consistent with those of (Amsalu & Graaff, 2007), who found a significant positive relation between age and the adoption of crop rotation (Amsalu & Graaff, 2007).

4.7 Farm size

Relating to farm size, a unit increase in the size of the farmland on average decreases the likelihood of adoption of fertilizer application and others by 0.9% and 1.4% respectively. Also, a unit increase the size of the farmland decreases the expected number of agronomic practices used by a farmer by 3.7%. This might be due to the fact that farmers with the large size of cultivated land have fear of incurring the cost of buying inputs like fertilizers. This result affirms with a study done by Deressa et al. in the Nile basin of Ethiopia to analyze farmers' perception and adoption to agronomic practices, which supports the notion that the negative relationship between farm size and adoption could be due to the fact that there are additional costs incurred as farm size increases.

4.8 Farming experience

A unit increase in the farming experience on average increases the likelihood of adoption of row planting, weed management and crop rotation by 6.4%, 0.3% and 0.3% respectively. Farming experience is useful in early stages of adoption of a given practice when farmers are still testing its potential benefits, which later determine its retention or dis-adoption over time. A probable explanation is that farmers with a lot of experience easily get information from extension personnel and other sources. Consequently, they tend to be aware of new developments in agricultural systems and hence assess and adopt new practices more often than younger farmers.

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4.9 Household size

A unit increase in the household size on average decreases the likelihood of adoption of crop rotation, and seed rate by 1.4% respectively. Also, a unit increase in the household size decreases the expected number of agronomic practices used by a farmer by 3.6%. On the contrary, the households with larger family size have the necessary labor to apply the recommended agronomic practices on their farm plots. This finding contradicts the finding by (Assaye1, Habte, & Sakurai1, 2023) which shows that family members are the main source of household labor for rice cultivation. Therefore, family size positively effects on adopting recommended agronomic practices.

4.10 Farmer group

Belonging to a farmer group compared to not belonging to a farmer group on average increases the likelihood of adoption of crop rotation, seed rate and others by 24.4%, 12.8% and 15.1% respectively. Also, belonging to a farmer group compared to not belonging to a farmer group increases the expected number of agronomic practices used by a farmer by 42.7%. This is because some farmers in the groups who are early adopters of certain practices can share testimonies (success stories) on the practices they tried, which can encourage other farmers to adopt those particular practices. Bandiera and Rasul (2006) also found that group membership enhances social networking, which facilitates the sharing of experiences about technologies and building confidence in those interested in the practices.

4.11 Access to credit

Accessing agricultural credit compared to not accessing agricultural credit on average increases the likelihood of adoption of fertilizer application by 13.6% but decreases the likelihood of adoption of seed rate by 16.8%. This is because credit provision has the advantage to solve financial constraints to meet their need to purchase the fertilizers. These results are in line with the findings from Deressa et al. and Gbetibouo who reported that farmers with more financial and other resources at their disposal are able to make use of all their available information to invest on the use of irrigation, use of agricultural inputs, use of drought tolerant crop species, use of SWC, and take up livelihood diversification in response to changing climatic and other conditions (Amare & Simane, 2017). However, accessing credit compared to not accessing credit for agricultural production decreases the likelihood of adoption of seed rate. This finding contradicts the above previous finding by Deressa et al. and Gbetibouo.

4.12 Summary of the findings

The adoption of various agricultural practices is influenced by several factors. Farmers with higher education (tertiary level), full-time farming status, and more farming experience are more likely to adopt row planting and seed rate practices. Similarly, higher education and access to credit positively influence fertilizer application, though this adoption decreases with secondary education and larger farm sizes. Increased farming experience enhances weed management adoption, while crop rotation is more common among married, divorced, or widowed farmers, older farmers, and those in farmer groups. However, crop rotation is less likely among full-time farmers, those with larger households, and those with credit access. Membership in farmer groups also drives the adoption of other agronomic practices like mulching and intercropping, though larger farmland sizes can deter this. Overall, the number of practices adopted increases with age but decreases with larger farm sizes and household sizes.

4.13 Recommendations

The adoption of row planting is positively influenced by having a tertiary education compared to no formal education. Therefore, agricultural support services, researchers, educators, and extension agents should focus on tailoring information dissemination channels based on farmers' education levels. This approach can better motivate farmers to make informed decisions and adopt row planting. Additionally, full-time farmers are more likely to adopt row planting than part-time farmers. As a result, the government of Uganda and relevant stakeholders should ensure that information on row planting reaches not only large-scale farmers, who are often full-time, but also small-scale farmers, given that agriculture is a cornerstone of Uganda's economy. Moreover, increased farming experience also promotes the adoption of row planting. Leveraging the knowledge of more experienced farmers in training and sensitizing less experienced or younger farmers on various agronomic practices could further enhance adoption rates.

The adoption of fertilizer application is positively influenced by having tertiary education compared to no formal education. Therefore, agricultural support services, researchers, educators, and extension agents should tailor information dissemination channels to farmers' education levels, ensuring they are more motivated to make informed decisions and adopt fertilizer application. Access to credit also positively impacts fertilizer adoption, highlighting the need for the government to strengthen rural financial institutions and farmer associations to offer credit, especially since smallholder farmers often face challenges in accessing credit. The government should also consider providing inputs such as fertilizer and herbicides on credit. Conversely, secondary education compared to no formal education negatively affects fertilizer adoption, suggesting that training programs should be equitable and cater to all education levels. Additionally, larger farm sizes discourage fertilizer use, indicating a need for farmers to be educated on the pros and cons of adopting agronomic practices based on their farm size, taking costs into account.

The adoption of weed management practices increases with farming experience, so experienced farmers should be involved in educating younger farmers about effective weed management techniques. Crop rotation is more likely to be adopted by married or divorced/widowed farmers than by single ones, making marital status a significant factor in adopting agronomic practices. Policymakers should consider marital status when designing incentives to encourage the adoption of multiple practices, ensuring that all farmers can maximize the benefits of crop rotation. Older age also positively influences crop rotation adoption, which suggests the need to create public social networking platforms, cooperative organizations, and activity centers where older farmers can mentor younger ones. Membership in farmer groups also promotes crop rotation, so forming or joining farmer groups focused on sharing agronomic information should be encouraged.

However, being a full-time farmer, as opposed to a part-time farmer, negatively affects crop rotation adoption, indicating that information on crop rotation should be targeted not only at large-scale, full time farmers but also at small-scale farmers, given Uganda's strong agricultural base. Larger household sizes also negatively impact crop rotation adoption, suggesting that farmers need to learn how to utilize their household size as a resource. Credit access also negatively impacts crop rotation adoption, reinforcing the need for policies that provide inputs on credit.

For seed rate adoption, full-time farmers and older farmers are more likely to adopt proper seed rates, highlighting the need for government and stakeholders to spread information about this practice to all farmers, including small-scale ones. Additionally, promoting the formation of farmer groups can enhance seed rate adoption. Other agronomic practices such as mulching, intercropping, and minimum tillage are also positively influenced by farmer group membership, further emphasizing the importance of farmer groups in disseminating information. However, larger farm sizes discourage the adoption of

these practices, indicating that farmers should be made aware of the pros and cons of different practices based on farm size, considering costs and efficiency.

Finally, the number of agronomic practices adopted increases with age, reinforcing the importance of community-based initiatives that allow older farmers to guide younger ones. On the other hand, larger farm sizes and household sizes negatively impact the number of practices adopted, suggesting that farmers need to be educated on how to turn these factors into assets rather than barriers to adopting agronomic practices.

V. DECLARATION OF COMPETING INTEREST

The authors of this paper declare no conflict of interest.

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