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Original article

DOES PLURALISTIC AGRICULTURAL ADVISORY SERVICE DELIVERY ENHANCE SUSTAINABLE LAND MANAGEMENT? EVIDENCE FROM SOUTHWESTERN UGANDA

Turinawe A[1]* and JH Ainembabazi[2]

Alice Turinawe

*Corresponding author: aaturinawe@gmail.com

[1]Makerere University, Uganda: College of Agricultural and Environmental Sciences, Department of Agribusiness & Natural Resource Economics, Uganda

[2]African Development Bank (ADB), Abidjan, Cote D'Ivoire

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ABSTRACT

Declining land productivity and increasing land and food scarcity, amidst high population growth have precipitated the need for intensification of crop production. Sustainable land management technologies (SLMTs) have been suggested as a way to support the intensification process. In Uganda, agricultural advisory services (AAS) geared towards improved adoption of the SLMTs are provided, and farmers can access AAS from diverse sources, with the possibility of accessing from single or multiple sources. This study attempts to identify and prioritize the drivers of farmers' access to (single/multiple) sources of AAS and determine the impact of access to these sources of AAS on the adoption of SLMT, and crop productivity. The study uses cross-sectional data collected from 435 households in the southwestern highlands of Uganda, in Kisoro and Kabale districts. The multinomial endogenous switching regression model combined with an endogenous switching regression model was used to analyse the data. Results indicate that both single and multiple sources of AAS have a positive effect on adoption of SLMTs and crop productivity, with the latter having a positive effect on the adoption of more SLMTs, while it seems to reduce the adoption of some other SLMTs. Similarly, accessing AAS from multiple sources has a higher positive impact on crop productivity, when compared to no access, but a lower impact when compared to access to a single source of AAS. These results suggest that access to multiple sources of AAS has positive impacts, but there are possible inherent challenges in the way it is implemented; lack of synchronisation of the messages given to the farmers, and the top-down approaches used to disseminate knowledge on SLMTs by some of the AAS providers may confound the possibly higher benefits of access to multiple sources of AAS. This study points out the need for policy to consider the advantages of having a streamlined agricultural extension system, with coordinated efforts from all agricultural advisory service providers and stakeholders.

Key words: Agriculture, advisory services, sustainable land management, switching regression, highlands, Uganda

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INTRODUCTION

The search for sustainable solutions is inevitable for declining land productivity arising from increasing population pressure on scarce arable land in developing countries. In Sub-Saharan Africa (SSA), 80 percent of rural farm households operate plots of less than 2 hectares per household [1], suggesting that crop intensification is unavoidable. Projections indicate that by 2050, 80 percent of growth in crop production in SSA is expected to come from increases in yield and cropping intensity, as opposed to arable land expansion [2]. However, the adoption of crop intensification and sustainable land management[1] technologies (SLMT) remains low [3, 4]. Evidence shows that enhancing the adoption of agricultural technologies requires that farmers have easy access to agricultural advisory services (AAS) [5] and [6] because some technologies such as SLMT are knowledge-intensive. Easy access to AAS means that the providers of AAS are within reach of farmers, suggesting that farmers' exposure to several sources of AAS may influence their decision to adopt agricultural technologies.

To-date, studies have hardly evaluated the impact of farmers' exposure to single or multiple sources of AAS on the adoption of SLMT and agricultural productivity. In fact, Ainembabazi *et al.* [7] finds that different sources of AAS delivery (government or non-government supported) have different delivery modes—training and visits, demonstration plots, farmer field days, and field schools—leading to heterogeneous impacts on a household's adoption decision. This study investigates the impact of farmers' exposure to a single source relative to multiple sources on the adoption of SLMT. Exposure to a single source of AAS likely exposes farmers to a particular delivery mode, while multiple sources of AAS expose farmers to different delivery modes. Different delivery modes have different implications for farmers' learning about the effectiveness of agricultural technologies [8], hence might result in varying impacts on crop productivity. As such, we further investigate how different sources of AAS affect farm productivity performance. Our study findings are not only relevant to policy formulation and reforms, but also agents of agricultural transformation need such compelling evidence-based guidelines to design AAS approaches that can successfully influence farmers' behaviour and attitude towards the adoption of SLMT.

[1] Sustainable land management is defined as "the use of land resources, namely, soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions" [6] and [7]. Sustainable land management includes practices that are geared towards soils and water conservation. Some of the practices include terracing, mulching, trash lines, contour cultivation, agro-forestry, inter-cropping, use of cover crops, fallowing, crop rotation, use of organic manure, trenches and diversion channels

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To help in understanding the role of different sources of AAS on technology adoption and farm performance, Uganda provides a suitable case study. As a means to improve information and service delivery, delivery methods in Uganda have evolved from a public monopoly of AAS to an interconnection of different advisory service providers, generally termed as "pluralistic agricultural advisory services" [11, 12]. Uganda's efforts towards pluralistic approaches have resulted in participation by multiple actors in service provision: (i) government agencies such as National Agricultural Advisory Services (NAADS); (ii) non-governmental organizations (NGOs); and (iii) farmer-based organizations such as cooperatives, farmer groups and farmer to farmer interaction. All these AAS delivery providers have SLMT as their component of farmer education, in response to the ever-increasing population pressure on limited land, especially for highlands areas. The highland areas of Uganda, which account for 27 percent of the country's land area and accommodate close to 40 percent of the total population, are the worst affected by land degradation [13, 14]. In the highland areas of southwestern Uganda where this study was carried out, diverse AAS providers work independently, but provide advisory services that are all geared towards improvement of land management practices and crop productivity. In addition to the government agricultural advisory service providers, some of the NGOs working in the studied districts include Nature Uganda, Africa 2000 Network, CARITAS and Care Uganda.

Evidence from the comparative evaluation of the performance and effectiveness of separate or combined extension service delivery methods is scarce [15], with calls for local advisory service delivery evaluation geared to improve the relevance of the service packages [16]. As Uganda settles into the single spine extension system (where the agricultural extension function is mainstreamed into the national agricultural system [17]), it is important to evaluate the current approaches to extension service provision. This study forms part of this evaluation.

MATERIALS AND METHODS

Study area

The study was conducted in the districts of Kabale and Kisoro, in the southwestern highlands of Uganda. The two are among the most densely populated districts in Uganda, with the population density estimated at 314 and 402 persons per sq. km, respectively [18]. The districts are characterized by hilly terrain that is highly susceptible to soil erosion and landslides. Efforts towards sustainable land management and conservation in these districts have become central to both government agencies and NGOs. In addition to government extension programs and farmer-based organizations, the districts have several NGOs disseminating

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sustainable land management technologies. There is, therefore, high heterogeneity in farmers' access to AAS.

Sampling procedure

Both purposive and random sampling procedures were employed. Two sub-counties were purposively selected per district, one with the highest concentration of AAS providers and another one with lowest concentration of AAS providers. From each of the selected sub-counties, one parish with the highest (lowest) concentration of AAS providers was again purposively selected. From each selected parish with high concentration of AAS providers, 6 villages were randomly selected, while 2 villages were randomly selected from the parish with low concentration of AAS providers. This form of sampling provides a high probability of finding villages and hence households with high (low) access to different sources of AAS providers. For each of the sampled villages, two primary sampling units (PSUs) were developed per village. One PSU was a list of all households that have access to AAS. The other PSU was a list of all households that have not had access to AAS. The lists were generated with the help of village leaders through a village census.

From each of the sampled villages from the parish with high concentration of AAS providers, at most 18 farm households with any members who had access to AAS and at most 10 farm households with no access to AAS were randomly sampled. From each of the sampled villages from the parish with low concentration of AAS providers, at most 10 farm households with any members who had access to AAS and at most 18 farm households with no access to AAS were randomly sampled. The analysis for this study uses a sample of 247 farm households with access to AAS (treated) and 188 farm households with no access to AAS (control) that were randomly selected from the two districts.

Analytical strategy

Consider household *h* exposed to different sources of AAS, living in village *v* (farmer and household are used interchangeably). The household seeks to access AAS to gain knowledge and skills to maximize adoption of SLMT with the view of increasing crop productivity. A farmer faced with a set of mutually exclusive AAS source alternatives (say *j* and *a*), will choose AAS_{hj} if it is expected to yield higher productivity than another alternative *a,* that is, $AAS_{hj} > AAS_{ha}, j \neq a$. This implies that the decision to access a particular AAS source is endogenously determined with the outcome variables (adoption of SLMT and crop productivity). To overcome this potential endogeneity, we use the multinomial endogenous switching regression model [19]. The model has an advantage of correcting the selection bias associated with access to AAS and evaluating alternative

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combinations of AAS sources or individual AAS sources as opposed to the multivariate framework. The model also controls for both the interdependence of the access decisions and selection bias due to observed and unobserved characteristics. The estimation of the multinomial endogenous switching regression model follows two stages.

The first stage uses the multinomial logit [20] to estimate the probability of a household choosing to access AAS source *j* and not any other alternative AAS as follows:

$$P_{hjv} = HCX_{hjv}\beta + e_{hjv} \quad (1)$$

Where P_{hjv} is the probability of accessing an AAS source j out of other alternative sources by household h settled in village v. HCX_{hjv} is the vector of household and community-level characteristics, β is a vector of parameters to be estimated, and e_{hjv} is the error term. The sources of AAS are classified as: no source, single source and multiple sources.

The second stage estimates the impact of AAS sources on adoption of SLMT and crop productivity (crop income per acre). By ignoring subscripts for simplicity, the general model of SLMT or crop productivity for each AAS source is as follows:

$$Y_j = X\alpha + \varepsilon \; if \; j = 1, 2, \dots, K \quad (2)$$

Where Y_j is the outcome (adoption of SLMT or crop productivity) at household level; X is a vector of household, plot and village level characteristics. α are corresponding parameters to be estimated and ε is the error term.

The major challenge, as aforementioned, is that the error terms in equations (1) and (2) are potentially correlated due to selection bias, leading to biased and inconsistent estimates. We use the multinomial endogenous switching regression model [19] to generate selection bias correction terms that are then included in equation (2) as additional regressors. The estimation of valid selection bias correction terms requires exclusion restrictions included in equation (1). That is, factors that directly influence the choice of AAS source but do not have a direct effect on adoption of SLMT and crop productivity. The number of extension agents disseminating SLMT in the community known by the farmer was used as exclusion restrictions. A farmer that knows a few extension agents is more likely to be connected to fellow farmers who know the same extension agents in the community. The farmer-extension-network connectedness at the community level is exogenous to individual households because it incorporates information diffusion from farmers who are informed by extension agents and fellow farmers, suggesting that there may be no difference in adoption of SLMT and crop productivity between farmers interacting directly with extension agents and fellow farmers. [21] find that farmers in communities with access to extension agents report fellow farmers as the main source of extension information, and that such community-level extension information does not have a direct impact on crop productivity of individual farm households.

The key question the study aims to answer is: What would have been the additional adoption rate (or productivity gain) had the farmer not accessed a particular number of AAS sources? Since the farmer cannot be observed as accessing AAS from a particular source and not accessing AAS at the same time, to answer this question requires counterfactual analysis. The multinomial endogenous switching regression model has the ability to generate counterfactual adoption of SLMT (or crop productivity) obtained by households that accessed AAS equal to the average adoption intensity (or average productivity) of those households that did not access AAS, with the same observable and unobservable characteristics [19]. Counterfactual adoption (or productivity) is derived in two steps. The first step estimates the expected adoption (or productivity) of households that accessed AAS sources $j = 1, \dots, T$; denoted as $E(X\alpha + A_j\sigma_j)$ for each of the AAS sources. Where $j = 0$ denotes household that did not access AAS sources, A_j is a set of selection bias correction terms generated from equation (1), σ_j are parameters to be estimated, and other elements are as earlier defined. The second step derives the counterfactual adoption of SLMT (or crop productivity) of farm households that did not access AAS source $(j = 0)$, denoted as $E(X\hat{\alpha}_0 + A_0\sigma_0)$ using coefficients derived from $X\alpha + A_j\sigma_j$ to generate predictions of counterfactual adoption of SLMT (or crop productivity) level: what the farm households accessing AAS source j would have adopted (or produced) if they had not accessed that AAS source. The difference between $E(X\alpha + A_j\sigma_j)$ and $E(X\hat{\alpha}_0 + A_0\sigma_0)$ gives the impact of adoption of SLMT (or crop productivity) associated with AAS source j.

RESULTS AND DISCUSSION

Socio economic characteristics of the sample households

Table 1 reports differences in the characteristics among farmers who did not access any source of AAS (44% of the sample), those who accessed AAS from a single source (29%) and those who accessed through multiple sources of AAS (26%). Overall, there are few differences in characteristics between farmers accessing AAS from a single source and those accessing from multiple sources. However, there are noticeable differences in characteristics between farmers with no access to any source of AAS and those accessing from at least one source. Households with no access to any source of AAS have smaller family sizes but with higher dependence ratio[2], have fewer members with post primary education, own smaller farm size and livestock, have less access to farmer groups and comparatively less credit services than those who access at least one source of AAS. These significant differences in characteristics suggest that the household's ability to access sources of AAS is potentially influenced by heterogeneity in household socio-economic characteristics.

Access to and participation in agricultural extension services

The availability of extension services was measured as the number of extension providers accessed by the farm households in the community. Although Table 2 shows that farmers had access to one extension service provider on average in a community, a considerable share of farm households in our sample had access to at least two extension service providers. Figure 1 indicates that about a quarter of the farm households had access to two extension service providers, while more than 10% had at least three service providers. Table 2 shows that about 57% of the households in our sample received extension and training services, with 53% receiving the services from one provider, while the rest received from multiple sources.

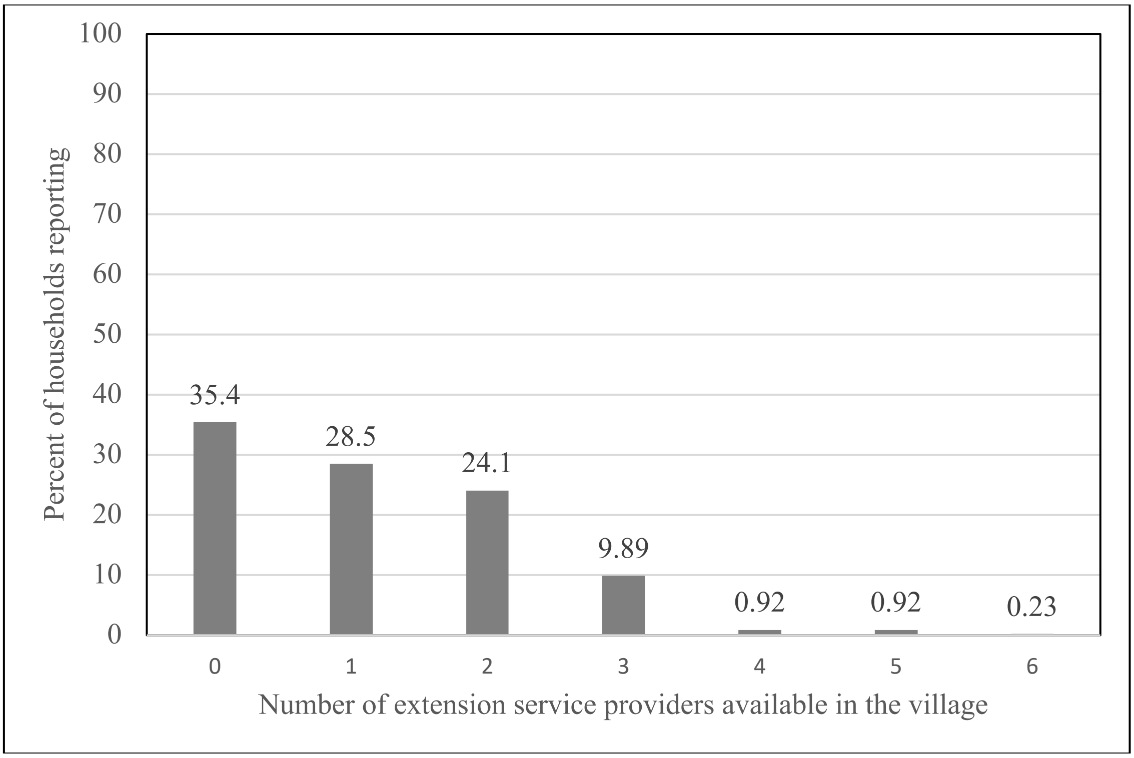

Figure 1: Number of extension service providers available in the villages

[2] The dependence ratio is defined as the sum of household members aged below 15 years and above 65 years to the household size

Adoption of SLMT and crop productivity by status of AAS source

The analysis presented in Table 3 seeks to establish a descriptive link between the number of sources of AAS and the adoption of SLMT as well as crop productivity. The adoption of a particular SLMT is defined as the use of that SLMT on the farmers' plots.

As indicated in Table 3, the common SLMT adopted in the study areas included those technologies that are mainly used for controlling soil erosion. This is expected, given the hilly nature of the study areas. More than a half of the surveyed sample (52%) use trenches or diversion channels, 41% use trash lines, 38% practice mulching crops, 36% fallow their land and 31% use grass or bench terraces, all of which are essential for controlling water run-off. The adoption level of other SLMTs ranges from 17% to 29%.

Importantly, the results show that there is a potential association between the adoption of SLMT and the number of sources of AAS accessed. The use of mulching, grass or bench terraces, *fanya juu*, cover crops and agroforestry is associated with farmers who have at least one source of AAS much more than those not utilizing AAS. For the rest of the SLMT, the difference in use of SLMT between farmers not utilizing any of the sources of AAS and those using them is marginal.

Similarly, there is no significant difference between non-users and users of sources of AAS and crop productivity. Crop productivity was measured as the sum of the value of crops produced per acre by individual households for the two cropping seasons preceding the survey. Crop market prices prevailing in each cropping season were used to generate the value of crop production. However, the descriptive analysis reported in Table 3 does not control for other factors, and therefore, the presented association between the source of AAS and the adoption of SLMT and crop productivity may be biased. The following sections present econometric approaches to establish the impact of access to (single/multiple) source of AAS on the adoption of SLMT and crop productivity.

Drivers of farmers' access to the source of agricultural advisory service delivery

Following the analytical approach described earlier, Table 4 reports the multinomial logit estimates. The farmers with no source of AAS is used as the reference group. The results show that male-headed households are more likely to access multiple sources of AAS compared to female-headed households. Gender is a key determinant of farm households' access to resources and information, including agricultural extension information [22]. Compared to men, women have been found to have limited access to agricultural extension information and resources necessary to implement agricultural technologies and hence are less likely to adopt agricultural technologies [23].

The results also show that relative to older farmers, young farmers seek out both single and multiple sources of AAS; the likelihood of seeking out a single source of AAS increases with the age of the household head up to 46 years, while it is up to 52 years for multiple sources. Beyond these age thresholds, the likelihood of seeking sources of AAS declines. The findings suggest that as household heads grow older, they are more likely to opt out of seeking AAS sources possibly because of declining energy associated with old age to travel long distances. Indeed, we find that the distance to the extension office is negative and statistically significant for the single source of AAS. That is, households located further away from the extension offices are less likely to choose a single source of AAS.

The share of household members with primary education is negative and statistically significant for both single and multiple sources of AAS. This suggests that households with a high proportion of members having primary education are less likely to choose single and multiple sources of AAS. In other words, this category of farmers is not likely to seek out AAS. It is possible that with more educated members, the household is likely to rely less on farming as a source of livelihood, with household members taking on other off-farm employment and consequently, a lower need for extension services.

Farmer groups play a significant role in disseminating agricultural extension information. Findings indicate that households whose heads have membership in farmer groups are likely to use single and multiple sources of AAS and less likely to use no source of AAS. Agricultural advisory services are more often provided to farmer groups and less often to individuals. Thus, it is expected that the AAS are more accessible when the household heads are members of farmer groups.

Distance to the nearest market is positive and statistically significant among those accessing a single source of AAS, and negative and statistically significant for the multiple source category, relative to the base category. This suggests that households that are located a long distance from the nearest market center are more likely to access a single source of AAS and less likely to access multiple sources of AAS. Results also show that a household with access to several markets is more likely to access a single source of AAS relative to no source of AAS. Similarly, access to credit positively and statistically significantly influences access to both single and multiple sources of AAS.

Farm size is also a key determinant of access to sources of AAS. Farm households with larger farm sizes have a higher likelihood of accessing single and multiple sources of AAS. Contrary, ownership of livestock discourages farm households from seeking out sources of AAS. Findings indicate that an increase in livestock size reduces the likelihood of farm households seeking out multiple sources of AAS.

Impact of sources of AAS on the adoption of SLMT

To understand how the number of sources of AAS accessed influences the farmers' decision to adopt SLMT, an analysis was done to compare the expected outcome values of adopters and non-adopters of SLMT following the methodology described in the analytical strategy section. The impact of source of AAS on adoption of SLMT is measured as the difference between the average adoption level of adopters (actual) and the expected average adoption level of adopters had they decided not to adopt (counterfactual). Similar characteristics to those reported in Table 4 were used. Table 5 reports the results.

Results show that the single source of AAS influences the adoption decision of farmers for a few SMLTs as compared to multiple sources of AAS. Particularly, a single source of AAS supports the increased adoption of mulching, trenches or diversion channels, and *Fanya juu* technologies. Among the sampled farmers, accessing a single source of AAS increases the probability of adopting mulching by 19%, trenches or diversion channels (13%) and *Fanya juu* (8%). Exposure to multiple sources of AAS has mixed impacts: On the one hand, exposure to multiple sources of AAS increases farmers' probability of adopting mulching by 9% followed by trash lines (7%), agroforestry (4%), and contour ploughing (1%). On the other hand, exposure to multiple sources of AAS can reduce the probability of adopting trenches or diversion channels by 13%, *Fanya chini* by (8%), *Fanya juu* (5%), grass terraces (5%), and hedges (1%).

Findings indicate that extension guidelines provided by extension agents from different organisations can deliver mixed or conflicting messages to farmers, leading to a possible negative net adoption effect and reduced efficiency in the implementation of SLMTs. In principle, exposure to multiple sources of AAS increases the quantity of knowledge. However, a model of herd behavior indicates that knowledge is not a necessary condition for adoption of agricultural technologies [24, 25]. Instead, Kondylis *et al.* [26] demonstrate that centralized training enhances the quality and credibility of the extension knowledge, suggesting that multiple sources of AAS may distort extension messages thereby leading to mixed impacts. Indeed, Kondylis *et al.* [26] find that adding an extra provider of AAS to an existing provider of the same had no impact on the diffusion of SLMT in Mozambique.

Economic implications of multiple sources of AAS on crop productivity

Another key focus of the study was to evaluate the impact of the number of sources of AAS on crop productivity. We compare single and multiple sources, and results are presented in Table 6.

The study findings show that the impact of the number of sources of AAS on crop productivity is highly significant at the 1% statistical level, but the largest productivity gains can be obtained when multiple sources of AAS are utilized. In particular, farmers who utilize multiple sources of AAS increase their crop productivity by nearly Ugx 3 million per year above non-users, while those using a single source increase their crop productivity by about Ugx 1.9 million per year. However, when a comparison was made between farmers using multiple sources and those using single source, the findings show that the latter yields higher pay-offs than the former. That is, farmers using a single source of AAS would increase their crop productivity by about Ugx 0.74 million higher than their cohorts. This finding further echoes the earlier argument that farmers who use multiple sources of AAS are likely to get mixed messages, which may potentially lead to inappropriate application of skills learned from providers, negatively affecting their crop productivity.

In the face of multiple service providers, some service providers may dictate the kind of services that they offer, which can contradict what farmers need. This negatively impacts both the effect on farm productivity and welfare, as well as the adoption of technologies that such service providers or their organizations may recommend [27]. Other studies (such as Sebaggala & Matovu [28]) find an insignificant contribution of extension services to improved farm productivity, and attribute it to poor quality of extension services. This suggests that the quality of AAS is important as opposed to the quantity that farmers can access.

CONCLUSION, AND RECOMMENDATIONS FOR DEVELOPMENT

The study investigates how farmers' exposure to multiple sources of agricultural advisory services (AAS) relative to single or none affects the adoption of sustainable land management technologies (SLMT) and crop productivity. The study uses data collected from smallholder farmers in southwestern Uganda. The findings suggest that irrespective of whether access is to single or multiple sources of AAS, access to either can contribute to the adoption of SLMT and improved crop productivity, compared to no access at all. Access to multiple sources is likely to contribute more to the adoption of sustainable land management technologies, compared to access to a single source. However, unlike access to single sources of AAS, access to multiple sources also seems to reduce the likelihood of adoption of some of the technologies. Similarly, both access to single source and multiple

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sources have a positive impact on crop productivity, compared to the no access scenario (the non-users of AAS). Compared to the no-access scenario, the multiple sources of AAS have a higher impact on crop productivity than access to a single source. However, when the impact of access to multiple sources of AAS is compared with a single source as the base, the single source is shown to have a higher positive impact on crop productivity. The study concludes that while access to multiple sources of AAS has positive impacts, there are possible inherent challenges in the way it is implemented, especially with packaging of the messages. These findings are attributed to possible lack of synchronisation of the messages given to the farmers, and the top-down approaches that are used to disseminate SLMTs by some of the AAS providers. This study, therefore, recommends that measures are put in place to coordinate and synchronise the contents of the messages that farmers receive. This can be achieved by creating arrangements for providers of AAS from different sectors to have a streamlined coordination of services provided.

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Table 1: Farmer characteristics differentiated by sources of AAS

Variable	Overall	Access to no sources of AAS	Access to single source of AAS	Access to multiple sources of AAS
Household characteristics				
Gender of household head (1, 0)	0.84 (0.37)	0.79^{a} (0.41)	0.86^{ab} (0.34)	0.87^{b} (0.34)
Age of household head (years)	48.52 (15.40)	49.03^{a}(17.90)	48.24^{a}(13.40)	48.00^{a}(13.09)
Household size	5.60 (2.30)	5.22^{a} (2.33)	5.81^{b} (2.20)	6.20^{b} (2.23)
Dependence ratio	0.42 (0.24)	0.45^{a} (0.24)	0.40^{ab} (0.02)	0.39^{b} (0.23)
Education level of head (years in school)	5.2 (4.2)	4.50^{a} (3.97)	5.48^{b} (4.43)	6.03^{b} (4.15)
Share of members with primary education	0.47 (0.29)	0.46^{a} (0.30)	0.45^{ac} (0.28)	0.53^{b} (0.28)
Share of members with post-primary education	0.18 (0.23)	0.13^{a} (0.21)	0.22^{b} (0.26)	0.21^{b} (0.22)
Farmer's experience (years)	24.77 (15.31)	24.94^{a}(17.67)	24.72^{a}(13.85)	24.54^{a}(12.64)
Resources ownership				
Total farm size owned (acres)	2.03 (6.95)	1.22^{a} (1.41)	2.60^{ab} (9.77)	2.70^{b} (8.31)
Total land rented-in (acres)	0.44 (6.00)	0.14^{a} (0.40)	1.10^{a} (10.88)	0.23^{a} (0.57)
Farm size cultivated (acres)	1.77 (5.69)	1.59^{a} (4.83)	2.04^{a} (8.26)	1.72^{a} (2.56)
Average distance to plot in minutes	20.34 (18.65)	21.69^{a}(22.16)	19.67^{a}(17.60)	18.90^{a}(12.53)
Tropical livestock units (TLU)	0.78 (2.12)	0.55^{a} (0.93)	1.04^{b} (3.31)	0.87^{b} (1.72)
Social capital and access to services				
Membership to a farmer group (1, 0)	0.67 (0.47)	0.42^{a} (0.49)	0.72^{b} (0.45)	0.86^{c} (0.35)
Distance to extension office (km)	5.07 (5.87)	4.87^{a} (4.98)	4.91^{a} (6.36)	5.57^{a} (6.60)
Access to credit (1, 0)	0.74 (0.44)	0.64^{a} (0.48)	0.77^{bc} (0.43)	0.86^{c} (0.35)
Head's leadership position in village (1, 0)	0.63 (0.48)	0.29^{a} (0.46)	0.47^{bc} (0.50)	0.55^{c} (0.50)
Distance to nearest market center (km)	4.01 (5.22)	3.74^{a} (4.53)	4.48^{a} (5.63)	3.91^{a} (5.74)
Distance to all weather road (km)	0.81 (2.66)	0.99^{a} (3.13)	0.90^{a} (2.99)	0.42^{a} (0.59)
Number of markets in the village	1.99 (0.94)	1.87^{a} (0.87)	1.98^{ab} (0.89)	2.20^{b} (1.08)
Number of observations	435	188	132	115

Notes: Different superscript letters between two categories indicate a significant difference level at p<0.1, while same superscripts indicate no insignificant difference between two categories. Standard deviation is in parentheses

Table 2: Availability of and household participation in agricultural extension services

Variable	
Access to extension and training services	N=435
Average number of extension service providers in the village	1.161 (1.120)
Percent of households receiving extension and training services	56.8
Percent of households receiving services from:	N= 247
One source of provider	53.4
Multiple sources of providers	46.6

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Table 3: Descriptive analysis of SLMT and crop productivity by source of AAS

Conservation technologies	Sources of AAS categories			
	Overall	Access to no sources of AAS	Access to single source of AAS	Access to multiple sources of AAS
Mulching	0.38 (0.49)	0.31[a] (0.47)	0.42[ab] (0.49)	0.44[b] (0.50)
Trenches/diversion channels	0.52 (0.50)	0.51[a] (0.50)	0.55[a] (0.50)	0.48[a] (0.39)
Trash lines	0.41 (0.49)	0.37[a] (0.48)	0.46[a] (0.50)	0.43[a] (0.49)
Fallowing	0.36 (0.48)	0.31[a] (0.47)	0.39 [a] (0.49)	0.40 [a] (0.49)
Contour ploughing	0.29 (0.45)	0.24[a] (0.43)	0.31[a] (0.47)	0.27[a] (0.45)
Grass/bench terraces	0.31 (0.46)	0.26[a] (0.44)	0.31[ab] (0.47)	0.38[b] (0.49)
Fanya chini	0.29 (0.46)	0.26[a] (0.44)	0.32[a] (0.47)	0.32[a] (0.47)
Fanya juu	0.23 (0.42)	0.18[a] (0.38)	0.29[b] (0.45)	0.27[ab] (0.41)
Minimum tillage	0.25 (0.43)	0.18[a] (0.39)	0.22[ac] (0.42)	0.38[b] (0.49)
Hedges	0.28 (0.45)	0.23[a] (0.42)	0.30[ab] (0.46)	0.34[b] (0.48)
Cover crops	0.23 (0.42)	0.20[a] (0.40)	0.21[ab] (0.41)	0.30[b] (0.46)
Agroforestry	0.28 (0.45)	0.22[a] (0.42)	0.31[ab] (0.47)	0.33[b] (0.47)
Crop rotation	0.17 (0.37)	0.19[a] (0.39)	014[a] (0.35)	0.17[a] (0.37)
Crop value (UGX/acre)	3,591,708 (4,548,215)	3,207,463[a] (4,454,373)	3,748,024[a] (5,159,619)	4,0404,39[a] (3,890,958)
Number of observations	435	188	132	115

Notes: Different superscript letters between two categories indicate a significant difference level at p<0.1, while same superscripts indicate no insignificant difference between two categories Standard deviation is in parentheses

Table 4: Multinomial Logit estimates of farmers' access to sources of AAS

Variable	Single source of AAS	Multiple sources of AAS
Male headed household (1, 0)	0.460 (0.658)	0.549** (0.259)
Age of household head (years)	0.278** (0.111)	0.309* (0.161)
Age of household head squared (years)	-0.003** (0.001)	-0.003** (0.001)
Household size	-0.047 (0.054)	0.081 (0.084)
Household head education (years in school)	-0.020 (0.081)	0.007 (0.051)
Share of household members with primary education	-0.723** (0.262)	-0.307** (0.139)
Share of household members with secondary education	1.056 (0.914)	-0.629 (0.385)
Dependence ratio	0.932 (0.641)	-0.073 (1.499)
Membership in farmer groups (1, 0)	0.834*** (0.145)	1.446*** (0.347)
Household head has leadership position in village (1, 0)	0.188 (0.129)	0.318 (0.210)
Log of distance to nearest market (km)	0.189* (0.112)	-0.187** (0.080)
Number of markets accessed	0.054* (0.032)	0.427 (0.287)
Log of distance to nearest all-weather road (km)	0.103 (0.209)	-0.115 (0.190)
Log of distance to extension office (km)	-0.796*** (0.208)	-0.349 (0.307)
Household accessed credit (1, 0)	0.062** (0.019)	0.485* (0.251)
Log of land size (acres)	0.375* (0.197)	0.403*** (0.048)
Log of tropical livestock units	-0.263 (0.294)	-0.674*** (0.189)
Average distance to operated plots (minutes)	0.014 (0.012)	0.030** (0.012)
Number of extension agents known in the village	2.615** (0.858)	4.568** (1.550)
Constant	-9.320** (2.861)	-16.273*** (3.929)
Number of observations		435

Note: Figures reported in parenthesis are standard errors in parentheses
***, ** and * represent significance level at 1%, 5% and 10

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Table 5: Effect of number of sources of AAS on incidence and intensity of adoption of SLMT

AAS source	Sustainable Land Management Technologies (SLMT)									
	Mulching	**Trenches channels**	**Trash lines**	**Fallowing**	**Contour ploughing**	**Grass terraces**	***Fanya chini***	***Fanya juu***	**Hedges**	**Agroforestry**
Single	0.188** (0.086)	0.133*** (0.001)	0.041 (0.218)	0.009 (0.045)	0.009 (0.219)	0.037 (0.114)	0.125 (0.139)	0.080** (0.033)	0.069 (0.059)	-0.059 (0.085)
Multiple	0.093*** (0.034)	-0.129*** (0.020)	0.072*** (0.02)	-0.073 (0.071)	0.014* (0.008)	-0.048*** (0.008)	-0.078*** (0.016)	-0.049*** (0.016)	-0.014*** (0.005)	0.044** (0.021)
Selection terms										
Λsingle	-0.268*** (0.054)	-0.250*** (0.067)	-0.035 (0.246)	-0.004 (0.145)	0.081 (0.381)	-0.096 (0.125)	-0.126 (0.217)	-0.051 (0.106)	-0.080 (0.105)	0.191*** (0.005)
λmultiple	-0.132 (0.081)	0.052 (0.084)	-0.075 (0.089)	0.164*** (0.015)	0.123*** (0.032)	0.155 (0.102)	0.198*** (0.066)	0.145* (0.077)	-0.02 (0.093)	0.029*** (0.001)

Note: Base group is no source of AAS. Sample size: 435. Standard errors in parentheses. * p < 0.1, ** p <0.05 and *** p < 0.01

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Table 6: Impact on crop productivity by number of sources of AAS

Treatment variable	Actual value of crop productivity (Ugx/acre)	Counterfactual value of crop productivity (Ugx/acre)	Impact (treatment effect, Ugx/acre)
Single source of AAS versus non-use	5,803,000 (311,210)	3,893,647 (211,577)	1,909,353*** (331,709)
Multiple source of AAS versus non-use	8,145,267 (467,210)	5,226,301 (335,412)	2,918,966*** (507,120)
Multiple source of AAS versus single source of AAS	5,063,100 (236,824)	5,803,000 (311,210)	-739,901*** (276,698)

Note: Figures in parantheses are standard errors. Significance levels: * p < 0.1, ** p <0.05 and *** p < 0.01

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