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Why Farmers Are Hesitant to Adopt What Appears Good on the Basis of Science: Understanding Farmers' Perceptions of Biophysical Research

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Abstract

This study conducted a series of extension events that were followed by farmer interviews with 394 farmers who had participated in an initial household survey in 2018, involving four farmer categories: 1] those actively participating in the Trees for Food Security (T4FS) project from phase 1 (2014); 2] farmers neighbouring those actively participating in the T4FS project from phase 1; 3] farmers actively participating in the T4FS project from phase 2 (2017) and; 4] farmers living distant and unaware of the T4FS project. The study drew upon knowledge generated from biophysical experiments on tree water use, shade tree planting and management in smallholder coffee-bean agroforestry systems to assess farmers' perceptions and willingness to adopt practices emanating from the study following exposure to the research outputs. The main form of extension used was through display and viewing of posters and a translated power point presentation of the research outputs on impact of tree canopy pruning on tree and coffee plant water use and productivity of coffee and common beans. We present the key messages obtained by the participants from the extension activities conducted, their preferred crop and management combinations, perceptions towards the research outputs and willingness to adopt the practices recommended by the study. We contend that smallholder farmers are hesitant to adopt innovations due to an underlying culture of financial expectancy leading to 'pseudo adoption', underutilisation of existing social networks during research and extension, period of exposure to a technology, and limitations in measuring and predicting adoption. We align the four farmer categories to the Process of Agricultural Utilisation Framework (PAUF) criteria, leading to a better understanding of the impact of research and development projects and agroforestry tree planting and management adoption pathways among smallholder farmers. This would enable introduction of socially and biophysically appropriate agroforestry interventions into local realities.

Keywords: participatory extension, agroforestry, adoption, social networks

1. Introduction

Agricultural innovations are seen as an important route out of abject poverty in smallholder farmers in developing countries. Researchers have traditionally been tasked with the development of improved agricultural technologies and their dissemination to extension officers and farmers. However, low adoption continues to hold large productivity, sustainability and resilience consequences for majority of farmers (BenYishay & Mobarak, 2019; Glover et al., 2019). There are many reasons for non-adoption of credible agricultural scientific research innovations in developing countries across the globe. Studies in Africa have revealed that farmers' lack of information on agricultural research outputs is not reflective of a lack of interest in obtaining research information, but the unavailability and inaccessibility of learning opportunities (Brown, et al., 2018; Mubofu & Elia, 2017). In cases where learning opportunities exist, the large heterogeneity of African smallholder farmers has further slowed down knowledge diffusion (Aker, 2011) and widened the information gaps. Deeper analyses have further revealed an underlying culture of financial expectancy (Brown, Llewellyn, et al., 2018) which limits farmer engagement in ongoing research activities, especially by research and development projects.

The low engagement of farmers in agricultural research has further been associated with weak linkages between researchers, extension workers and smallholder farmers (Brown, Nuberg, et al., 2018). A lack of interest among farmers to seek well-researched information (Acheampong et al., 2017; Owolade & Arimi, 2012) further slows down diffusion of knowledge of new technologies and practices. While many countries hire agricultural extension agents to communicate with farmers about new technologies, a large academic literature has established that integrating social networks is a key determinant of adoption (Beaman et al., 2015; BenYishay & Mobarak, 2019; Young, 2009). Existing social networks in a community are locally trusted channels through which agricultural information can be delivered to other farmers.

Failure to reliably measure and predict adoption has led to over- and under-estimation of adoption levels of agricultural technologies and practices. Recent frameworks including the Process of Agricultural Utilisation Framework (PAUF) proposed by Brown et al., (2017) and a modified smallholder Adoption and Diffusion Outcome Prediction Tool (ADOPT) framework (Llewellyn & Brown, 2020) are major steps towards a better understanding of agricultural technology adoption pathways. Such frameworks can contribute towards obtaining adoption constraints of a farming community. Therefore, adoption is not only related to technology, socio economic and behavioural factors and the research and extension methods applied, but a result of complex interactions between people, technologies and institutions (Kiptot et al., 2007; Takahashi et al., 2019). In this study, the PAUF is applied to four farmer categories at different levels of interaction with an Australian Centre for International Agricultural Research (ACIAR) funded Trees for Food Security (T4FS) Project.

Unlike agricultural crops, agroforestry adoption is a dynamic process involving farmer experimentation that occurs over a long period with almost no immediate benefits (Kiptot et al., 2007). However, even where traditional agroforestry research has successfully been conducted, the outputs may not be suitable or usable to the farmer for reasons not identified in the initial study. For example, while assessment of tree-water use, tree management and associated crop yield data may appear acceptable to the research community and worth promoting (Buyinza et al., 2019; Namirembe et al, 2008), it may not be socially acceptable to the user communities. Therefore, understanding farmer perceptions about shade tree management and its impact on tree water use and crop productivity would help reveal farmers' propensity to adopt tree canopy pruning.

The primary users of agroforestry research, namely farmers, think in a cross-disciplinary perspectives about their enterprises and not simply distinct 'silos' (Galmiche-Tejeda, 2004). Using an interdisciplinary research (IDR) approach is suitable to address such modern requirements in agriculture, given its complex nature that combines social and environmental factors (Morse et al., 2007). Interdisciplinary research is motivated by a general belief that by drawing information from different fields and employing different methodologies, a broad understanding and new perspective on an existing issue can be achieved. In addition, IDR is useful in providing a valuable opportunity for engagement with the user communities of the research, making it socially relevant (Gibson et al., 2018; Lowe & Phillipson, 2006). Low engagement with user communities (for example, farmers) often results in research outcomes that lack sufficient relevancy to the intended user community. Therefore, IDR creates opportunities for participatory research, while encouraging collaboration between researchers and farmers to create linkages between available biophysical and social economic information. Intrinsic to the nature of smallholder agroforestry farming systems in the Mt. Elgon region are the underlying relationships that exist between their human (farmer perceptions, knowledge and attitudes) and agro-ecological components (coffee, trees and common beans). This study therefore draws upon knowledge generated from biophysical experiments to assess changes in perceptions from farmers with different levels of exposure to biophysical information on agroforestry tree planting and management in coffee-bean systems in the Mt. Elgon region of Uganda.

2. Conceptual Framework

The study had an initial phase of in-depth, semi-structured farmer interviews and generation of biophysical information from two selected farms with *Cordia africana* and *Albizia coriaria* trees integrated with coffee and common beans (Figure 1). The biophysical information generally relates to influences on the physical production process associated with farming – the impact of tree management on water use and productivity of coffee and common beans, for the case of this study. Farmer interviews would establish farmers' underlying perceptions and motivations towards adoption of trees in their farming systems [see (Buyinza. et al., 2020a, 2020b, 2021)], while the biophysical experiment assessed the impacts of trees and their management on crop productivity and tree water use [see Buyinza et al., (2019)]. The biophysical experiment assessed water use in selected *C. africana, A. coriaria* and coffee trees and yield of coffee and common beans planted on the same piece of land. *C. africana* and *A. coriaria* trees were subjected to a 50% pruning regime at a 6-month interval over a period of 20 months (July 2018 - February 2020). The information from the biophysical data was then reported to farmers through a series of extension events. The extension events were used to highlight the relevance of the findings to the farmers and assess the appropriateness of the extension methods used to deliver the biophysical information to the farmers. The participants of the extension activities were the same farmers that had participated in the initial farmer survey under the same farmer categories used by Buyinza et al (2020a).

The extension events were then followed by a second phase of interviews (which is the focus of this paper) that would assist in assessing any changes in farmer perceptions towards planting and management of trees on their farms and their willingness to adopt the recommended practices. This process involved revisiting participants of the initial survey and presenting findings from the biophysical experiment so that they could provide additional feedback, comments and opinions on the results. Obtaining feedback and later integrating it with the biophysical information would enable introduction of socially and biophysically appropriate agroforestry interventions into local realities. Farmers did not have to necessarily agree with the findings of the biophysical study. The project was also interested in collecting the views of the dissenting farmers for documentation and further inquiry.

Lastly, all the data and information collected from the second phase of farmer interviews and the biophysical experiment was then used to establish the potential impact of incorporating *Cordia africana* and *Albizia coriaria* on soil water resources and crops productivity. The potential impacts resulting from adoption of biophysical information would be documented for informing policy decisions relating to agroforestry and household food security.

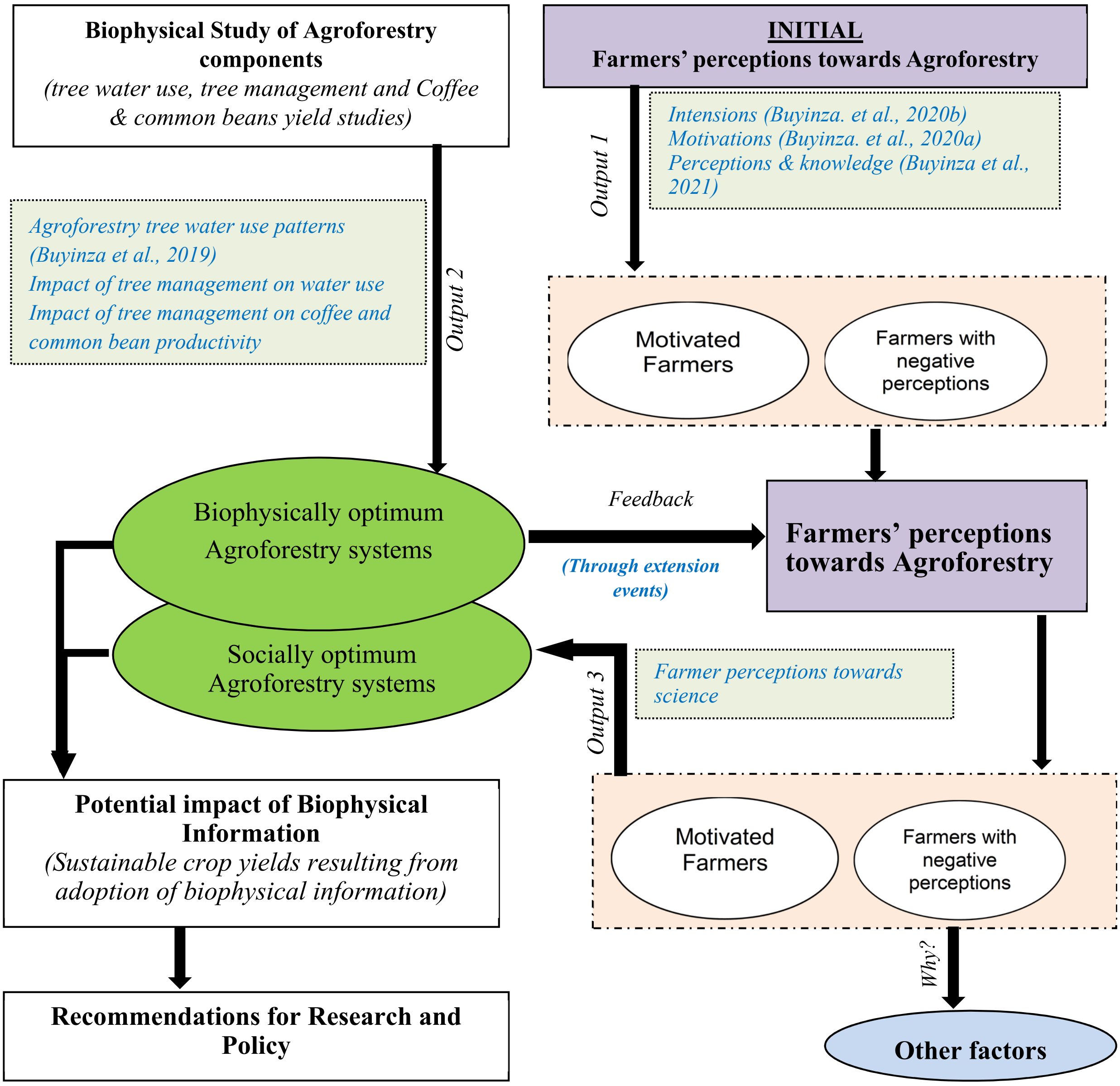

Figure 1. Overall conceptual framework for the study

3. Methods

3.1 Study Area

This study was conducted in three districts including Manafwa, Bududa and Sironko, located in Mt. Elgon region of Uganda. About 98% of the human population in this region is rural based, with an annual population growth rate of 3.4%. In terms of climate, the average annual rainfall is 1500 mm, with two peak rainy seasons that occur in the months of April–June and August–November.

3.2 The Trees for Food Security (T4FS) Project in Eastern Africa

The study sites form part of the Trees for Food Security (T4FS) project sites. The T4FS was an Australian Centre for International Agricultural Research (ACIAR) funded project implemented by World Agroforestry (ICRAF) in partnership with national level stakeholders. The project aimed at improving household food security and smallholder livelihoods through widespread adoption of appropriate locally adapted agroforestry practices in key agricultural landscapes in Ethiopia, Rwanda and Uganda. Since 2012, the project has been reaching out to smallholder farmers in rural regions where an estimated 10 million people are facing acute food security problems since 2012. The second phase of the T4FS project (2017 – 2021) focused on tree diversity as the cornerstone of smallholder system intensification and integrated tree management with value chain development and sustainable water management.

The T4FS project has established that trees in fields, farm and landscape niches can provide products and services that underpin and improve food security through system intensification and management of interactions amongst components. Agroforestry technologies such as fodder banks, boundary planting, riverbank restoration using trees, scattered trees on-farm, woodlots and use of vegetation strips to control soil erosion have been widely promoted among some of the most vulnerable farming communities in the Mt. Elgon region of Uganda.

3.3 Research Design

The study used existing records and the local council leadership to trace back the same respondents that had participated in the initial farmer survey in 2018 (May – July) (Buyinza. et al., 2020a, 2020b) for the extension events. The same farmer categories used in 2018 were also maintained. The farmer categories were: 1] those actively participating in the T4FS project from phase 1 (2014); 2] farmers neighbouring those actively participating in the T4FS project from phase 1; 3] farmers actively participating in the T4FS project from phase 2 (2017) and; 4] farmers living distant and unaware of the T4FS project.

3.4 Data Collection

3.4.1 Conducting Extension Events

To ensure adherence to the Covid-19 Standard Operating Procedures (SOPs) and Ministry of Health (MoH) guidelines, strategic venues that would accommodate 20-30 people were identified within the communities. Undertaking the extension events close to the communities increased the chances of attaining high participant turn up for the extension events. The participants were also informed about the event a week prior, to give them time to plan for the event. The final reminders were made 2 days to each extension activity through phone calls (for farmers with phones) and verbally through their respective village local council chairpersons. At each venue, copies of two posters were displayed for farmers to view in the first 20 minutes. The posters were entitled (1) A practice for managing agroforestry trees increases coffee and common beans yields and (2) Save water for agriculture by pruning trees (Figure B1 and B2). The next 20 minutes were then used to go through the posters in the local dialects in 2 separate groups (men and women separately). The groups would then come together for a power point presentation prior to individual farmer assessment and interviews. These activities (poster viewing, poster presentation in local dialects and power point presentations) were conducted to ensure that the participants understood the message being delivered (IIik & Rowe, 2013).

3.4.2 Testing Participants' Understanding of the Information Delivered

We got feedback from each participant regarding the key messages and anything new they had learnt from the activities conducted. This would help ascertain participants' understanding of the information delivered.

3.4.3 Assessing Changes in Farmer Perceptions Following the Extension Activities

The study assessed changes in farmers' perceptions after exposure to biophysical information on agroforestry tree planting, water use and management in coffee-bean systems in the Mt. Elgon region. The assessment sought farmers perceptions on planting and management of shade trees, a comparison of coffee growing under pruned and unpruned trees, as well as general opinion on shade tree planting and management, following the perceived practice characteristics (Rogers, 2003). The perceived practice characteristics also known as Rogers' factors of adoption (observability, relative advantage, complexity, trialability and compatibility) were also applied in the initial farmer survey prior to exposure to biophysical information (Buyinza. et al., 2020a, 2020b). A total of 394 farmers participated in the extension events and were interviewed. The high turn-up was achieved through effective mobilization using local council leaders, with an indication that a modest transport facilitation would be provided to ease movement and a snack during each extension event. However, while 4 respondents (among the farmers living distant and unaware of the T4FS project) declined to attend the extension events and could not be interviewed, 2 farmers (among farmers neighbouring those actively participating in the T4FS project) could not be traced in the community, as we were reliably informed they had migrated from the area.

3.5 Data Analysis

Data from the farmer survey conducted following each extension event was checked for consistency, coded and entered into Statistical Package for Social Scientists (SPSS version 25) software for analysis. Descriptive statistics were used to generate summaries from the data in form of frequency tables and histograms. Analysis of variance was used to determine whether any differences existed in farmers' perceptions of different crop combinations and tree management options considered more beneficial and sustainable to their households.

4. Results

4.1 Socio Economic Characteristics of the Respondents

Overall, out of the 394 respondents interviewed, 228 (58%) were males with a uniform distribution of male and female respondents across the four farmer categories. Over 50% of the respondents were aged between 31 and 50 years and the majority had only attained primary education (68%); over 60% owned less than 2 acres of land. About 70% of the households had 4-7 family members, and active farm work was mostly done by less than 3 males and females household members.

4.2 Assessment of Participants' Level of Understanding the Message Delivered

Overall, 71% of the respondents understood that pruning could increase coffee and common bean yields, as the key message received from the extension activities, mainly reported by project beneficiaries in both phases 1 and 2 (83 and 86 out of 100 participants respectively) (Table 1). Another key message was that pruned trees use less water than unpruned trees, reported by 59 out of 100 respondents belonging to the farmer actively participating in the T4FS project from phase 1 (2014). The key messages were better understood by farmers directly interacting with the project, probably because the same message had been delivered to them multiple times during project activities. Unlike the farmers neighbouring the project beneficiaries and those living far and unaware of the project, it was not the first time majority of the project beneficiaries were learning about this information. However, 8 participants (distributed across all the farmer categories) understood that beans planted in open fields give very low yields, contrary to the message delivered during extension activities. This may imply that the extension method of displaying posters was not appropriate for them, as they misunderstood the message being displayed.

Table 1. Key messages picked by farmers from the extension activities conducted

	Respondent category				
Variable	**Farmer actively participating in the T4FS project from phase 1 (2014)**	**Farmer neighbouring those actively participating in the T4FS project**	**Farmer actively participating in the T4FS project from phase 2 (2017)**	**Farmer living distant and unaware of T4FS project**	**Total**
Pruning can increase coffee and bean yields	21.1 (83)	17.7 (70)	21.8 (86)	9.9 (39)	70.6 (278)
Pruned trees use less water than unpruned trees	15.0 (59)	8.6 (34)	10.2 (40)	12.4 (49)	46.2 (182)
Pruning allows cultivation of beans for a long time	8.7 (34)	7.1 (28)	7.1 (28)	6.9 (27)	29.8 (117)
Pruning allows coffee and beans to access light	10.9 (43)	5.1 (20)	4.1 (16)	6.9 (27)	26.9 (106)
Unshaded coffee uses more water than shaded coffee	5.3 (21)	5.8 (23)	7.1 (28)	1.0 (4)	19.3 (76)
Albizia seems to be the best tree for integrating in coffee	4.3 (17)	2.6 (10)	4.3 (17)	2.6 (10)	13.7 (54)
Pruned branches and leaves add manure to soil	4.1 (16)	2.5 (10)	4.6 (18)	2.3 (9)	13.5 (53)
Pruning increases farm income from sale of coffee and beans	3.6 (14)	4.3 (17)	2.3 (9)	3.0 (12)	13.2 (52)

Shaded coffee can give higher yields than unshaded coffee	1.8 (7)	3.3 (13)	2.0 (8)	5.3 (21)	12.4 (49)
Beans give very low yields in open fields	0.0 (0)	0.0 (0)	1.3 (5)	2.6 (10)	3.9 (15)
It is possible to prune large trees without damaging coffee	1.0 (4)	0.5 (2)	0.5 (2)	1.0 (4)	3.0 (12)
Pruning should be done by a trained person	0.5 (2)	0.5 (2)	0.3 (1)	0.8 (3)	2.0 (8)

Frequency in parenthesis

The participants were asked to give one convincing and most important reason that would encourage them to plant and manage trees in their coffee gardens. The main convincing and important reason was the higher coffee yields from shaded coffee, followed by the prolonged period of intercropping (with common beans) under pruned trees and the higher income from shaded combinations (Table 2). Overall, a total of 184 farmers of the 394 participants (47%) were convinced that higher coffee yields can be obtained from shaded coffee. This implies that over 50% of the participants were not convinced (by the data presented to them) that higher yields could be obtained from shaded coffee. These farmers are still hesitant to change, as majority of them prune only when there is need for fuelwood and / or poles.

Table 2. The main convincing and important reason that would encourage farmers to plant and prune shade trees on their farms

	Respondent category				
Variable	**Farmer actively participating in T4FS project from phase 1 (2014)**	**Farmer neighbouring those actively participating in T4FS project**	**Farmer actively participating in T4FS project from phase 2 (2017)**	**Farmer living distant and unaware of T4FS project**	**Total**
Higher coffee yields from shaded coffee than unshaded coffee	14.4 (56)	10.8 (42)	12.1 (47)	10.0 (39)	47.1 (184)
Pruning prolongs the period of intercropping	4.6 (18)	5.6 (22)	6.4 (25)	5.9 (23)	22.4 (88)
More income from shaded combinations	4.6 (18)	4.3 (17)	4.9 (19)	4.3 (17)	18.2 (71)
Pruning reduces competition for water	0.8 (3)	2.6 (10)	0.5 (2)	1.8 (7)	5.6 (22)
Pruning may control pests and diseases in coffee	0.8 (3)	1.3 (5)	1.5 (6)	1.0 (4)	4.6 (18)
Coffee appears to use more water when under pruned trees	0.5 (2)	0.5 (2)	0.3 (1)	0.8 (5)	2.0 (8)

Frequency in parenthesis

Surprisingly, only 56 out of the 100 farmers actively participating in the T4FS project were convinced that higher coffee yields can be obtained from shaded coffee (Table 2). It is likely because the majority of the farmers who had commenced pruning shade trees (after learning from the experimental sites) were yet to realize yield increases due to the short study period following pruning, as majority had only pruned once by the time extension activities were held. Additionally, the farmers needed more time to interact with the experimental sites and the 20-month period of the study may not have been enough to convince them. This may also be responsible for the few participants that were convinced that more income can be generated from shaded combinations, that pruning prolongs the period of intercropping, and that pruning can reduce competition for water and control pests and diseases following reduction of shading effect on coffee. This may also be an indication that farmers may not be convinced to adopt new practices by simply word of mouth, but require other methods of engagement such on-farm demonstrations and social networks.

4.3 Farmers' Ranking of Different Crop Combinations and Tree Management Options

Farmers' ranking of different crop combinations and tree management options considered more beneficial and sustainable to the household is presented in Table 3 below. Apart from the combination involving pruned Albizia, coffee and beans and the combination involving pruned Cordia, coffee and beans ranked as either first or second most beneficial crop combination, none of the farmers' rankings were consistent with the ranking based on the research results that were presented. Ranking crop combinations involving pruned trees as the most beneficial could be attributed to the additional benefits that can be accrued from pruning. These benefits include additional organic matter from pruned branches and leaves, fuelwood and reduction of negative shading effects that prolongs the period of intercropping below pruned trees.

An analysis of variance further revealed significant differences in farmer opinions on 5 out of the 11 different crop combinations and tree management options ($P<0.05$) (Table A). This is mainly predominant in crop combinations that have common beans as one of the components. It was outstanding that farmers living at distance and unaware of the T4FS project ranked planting of common beans in open field as the third most beneficial option. The point of contention here was that some farmers whose main cash crop was common beans did not perceive any need to integrate trees in their gardens. They would instead prefer to plant common beans in open fields, where the research results indicated the highest yields of common beans would be achieved. The differences in the ranking of the crop combinations among farmer categories and the ranking based on research results could further imply that farmers may not entirely adopt the crop combinations suggested by the project. They could still have other underlying reasons for not adopting the crop combinations as some indicated that they needed to either first try it out or observe from other farmers before adopting them on their farms.

Table 3. Ranking of crop combinations and tree management options considered more beneficial and sustainable to the household

Crop combinations and tree management options	Ranking based on farmer's own perspective* and project results				Ranking based on research results presented
	Farmer actively participating in T4FS project from phase 1 (2014)	Farmer neighbouring those actively participating in T4FS project	Farmer actively participating in T4FS project from phase 2 (2017)	Farmer distant and unaware of T4FS project	
Pruned Albizia + coffee + beans	1	1	1	2	1
Pruned Cordia + coffee + beans	2	2	2	1	2
Coffee only but under pruned Albizia	4	5	4	4	3
Unpruned Albizia + coffee + beans	3	3	3	7	4
Coffee only but under pruned Cordia	5	8	5	11	5
Coffee only but under unpruned Albizia	8	7	11	9	6
Beans + Unshaded coffee	7	10	10	8	6
Unpruned Cordia + coffee + beans	9	11	8	4	8
Coffee only but under unpruned Cordia	10	9	6	10	9
Unshaded coffee only	11	4	7	6	10
Beans in open field	6	6	9	3	11

**Ranking based on farmer's own capability (e.g resources/tools and skills to prune) and perceived need/desire to change from current practice.*

4.4 Attitudinal Measurable Variables on Planting and Management of Shade Trees

The attitudinal measurable variables were assessed based on perceived practice characteristics that represent Rogers' factors of adoption (Table 4). Despite the significant difference in opinion ($p<0.05$), the respondents generally agreed that shaded gardens had more general benefits than unshaded gardens (relative advantage) and that tree planting was compatible with existing farm practices at L5.35 and L5.04 respectively on a scale of 1-7 (Table 4). Unlike the neighbours and remote farmers (that were uncertain), those interacting with the project (both Phase 1 and 2 farmers) strongly agreed that a garden shaded with trees has more general benefits than an unshaded garden. This may be attributed to the additional benefits the project beneficiaries had observed in shaded systems while interacting with the T4FS project. All the farmer categories did not find tree planting complex and would not consider that they needed to plant shade trees on a small scale first before planting more extensively. Apart from the remote farmers, other farmer categories would not require previous observation of other farmers planted trees before doing the same (Table 4).

Table 4. Group-specific descriptive statistics ‘‘mean (standard deviation)’’ of attitudinal measurable variables on plating and management of scattered trees on-farm on a scale of 1–7 and Analysis of variance (ANOVA) between different variables and farmer categories (p value)

Statement	Phase 1[a]	Neighbours[a]	Phase 2[a]	Remote[a]	Total	*P* - value
Statements on scattered trees in coffee gardens						
A garden shaded with trees has more general benefits than an unshaded garden *(Relative advantage)*	6.46 (0.58)	4.13 (1.12)	6.24 (0.65)	4.49 (1.36)	5.35 (1.42)	0.000**
Planting trees in the garden is compatible with existing farm practices *(Compatibility)*	5.93 (0.80)	4.02 (1.18)	5.80 (0.74)	4.38 (1.34)	5.04 (1.34)	0.033*
Planting trees for shade is too much trouble for what it is worth *(complexity)*	3.16 (1.27)	2.36 (0.79)	3.10 (1.03)	2.48 (0.97)	2.78 (1.09)	0.060
I am likely to plant trees in my garden after seeing other farmers doing the same *(Observability)*	1.94 (1.10)	2.63 (1.89)	2.73 (0.86)	4.39 (1.52)	2.91 (1.65)	0.050*
I am likely to plant shade trees on a small scale first before planting more *(Trialability)*	2.53 (1.19)	4.50 (1.77)	2.67 (1.06)	4.36 (1.85)	3.50 (1.76)	0.033*
Comparing coffee growing under pruned and unpruned trees						
A garden with pruned trees has more general benefits than one with unpruned trees *(Relative advantage)*	6.07 (0.66)	4.53 (1.13)	5.99 (0.90)	4.81 (1.39)	5.36 (1.25)	0.001**
Pruning trees in coffee would not affect my other farming activities *(Compatibility)*	5.04 (1.36)	3.21 (1.40)	5.35 (1.16)	3.70 (168)	4.34 (1.66)	0.000**
Pruning trees in my coffee garden is too much trouble for what it is worth *(Complexity)*	1.82 (1.13)	5.92 (1.52)	3.96 (1.44)	5.95 (1.39)	4.41 (1.88)	0.000**
I am likely to prune trees in my garden after seeing other farmers doing the same *(Observability)*	3.16 (1.25)	3.06 (1.48)	3.17 (1.29)	5.81 (1.54)	3.55 (1.63)	0.240
I am likely to prune trees on a small scale first before pruning the rest in my garden *(Trialability)*	5.92 (0.89)	4.43 (1.34)	5.95 (0.69)	4.83 (1.10)	5.29 (1.23)	0.000**
I intend to prune trees existing in my coffee garden in the next 5 years *(Intension)*	6.02 (0.64)	5.91 (0.89)	5.95 (0.69)	4.44 (1.42)	5.29 (1.23)	0.000**

*[a]Phase 1= farmers actively participating in the T4FS project from phase 1 (2014); Neighbour= farmers neighbouring those actively participating in the T4FS project from phase 1; Phase 2= farmers actively participating in the T4FS project from phase 2 (2017) and; Remote= farmers living distant and unaware of the T4FS project. N=394; df = 3; *significant at 5% significance level; **significant at 1% significance level.*

In terms of tree canopy pruning, project beneficiaries strongly disagreed that pruning trees was too much trouble for what it is worth, while their neighbours and remote farmers strongly agreed (Table 4). The project beneficiaries did not regard pruning as a complex undertaking probably because they had been trained by the T4FS project on how to prune shade trees in coffee gardens. Unlike other farmer categories, the remote farmers strongly agreed that they needed to first see others prune before doing the same (Table 4). This could imply that the extension activities could not change the perceptions of remote farmers and would want to first observe others pruning trees before they undertook pruning on their farms, an indication that tree pruning is regarded a difficult and risky task to do, as many farmers fear damaging their coffee during pruning. However, all farmer categories exhibited a high intention to prune trees existing in their coffee gardens within the next 5 years.

While the information given during the extension events would encourage majority of the farmers to plant and prune shade trees, a few farmers (23 farmers) would not be encouraged by the information, the majority of whom were non-project beneficiaries (Figure 2). The dissenting farmers reported that their focus was common beans which yield more in open fields while others had too many farm activities to allow time for pruning.

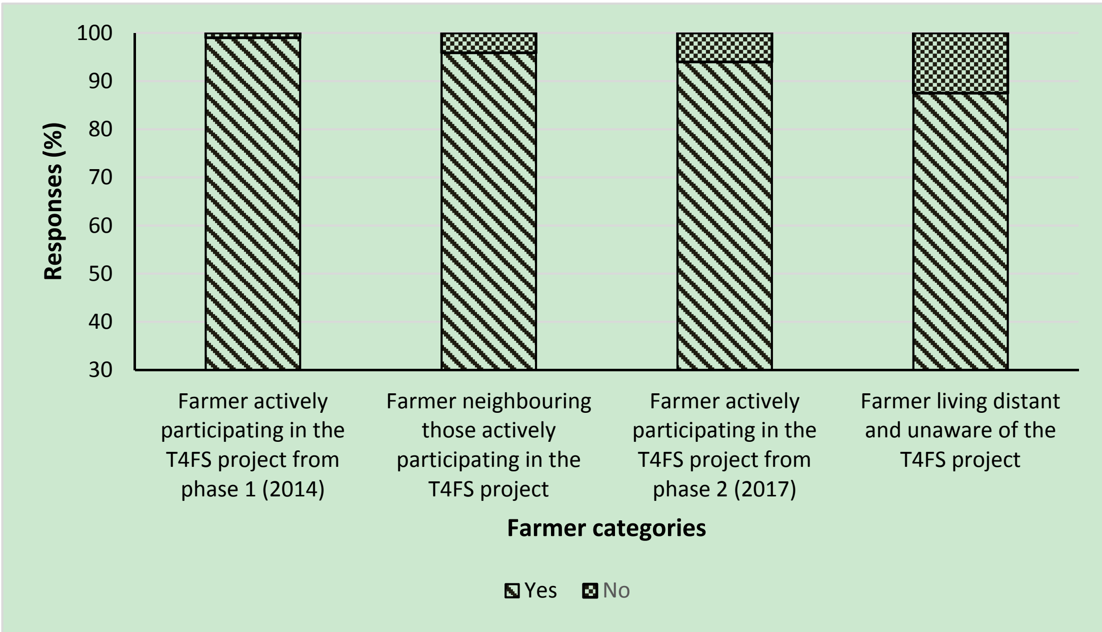

Figure 2. Whether the information given would encourage farmers to plant and prune shade trees

5. Discussion

The discussion highlights the history of agricultural extension in Uganda from the colonial government to the present single spine extension system. The section also provides an assessment of farmer perceptions of shaded coffee and management of shade trees following the extension events, the adoption process of smallholder farmers and the impact of development projects on agricultural technology adoption. We finally present the key drivers of agricultural technology adoption among smallholder farmers in the context of developing countries.

5.1 Uganda's Agricultural Extension System

Agricultural extension in Uganda has been changing since its introduction by the colonial government in the late 1800s, with a number of approaches applying regulatory, advisory and educational methods (Hakiza et al., 2004; Mangheni et al., 2003). Semana (1999) identified seven evolutionary phases in agricultural extension in Uganda as (1) Regulatory service: 1920-1956, (2) Advisory Education: 1964-1971, (3) Dormancy: 1972-1981, (4) Recovery: 1982-1999, (5) Educational: 1992-1996, (6) Participatory education: 1997-1998 and (7) Decentralized Education 1997-2001. Following the introduction of contractual extension services between 2001 – 2014 under the National Agricultural Advisory Services (NAADS), the government of Uganda introduced a single spine extension system in 2015 (MAAIF, 2015) in an attempt to further reform the country's agricultural extension system.

A decentralized extension system (1997 – 2001) transferred responsibilities and functions of planning and implementation of agricultural extension services from the mainstream Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) to district local governments. MAAIF was left with the responsibility of planning and policy formulation, regulatory functions, technical backstopping, setting standards and monitoring performance of the agricultural sector, and managing funds of selected projects (Bashaasha et al., 2011). As a result of decentralization, provision of extension services was mainly a responsibility of the district-level government where districts would pay for most of the operational expenses while staff salaries would be paid by the central government (Anderson & Crowder, 2000). Public extension faces several challenges such as weak research and extension, bureaucracy, non-participatory approaches and lack of response to farmers' needs (Buyinza et al., 2015). It was anticipated that the introduction of NAADS would eliminate these bottlenecks through a contractual privatized system, where farmers would pay 50% funding of advisory services within the next 25 years. This would also enhance sustainability of farmer groups and emergence of new farmer organizations (Bekywaso, 2006). In this system the local governments would contract private firms, farmer associations or NGOs to provide extension services (Bashaasha et al., 2011).

5.1.1 Extension through the NAADS System

The NAADS Act of 2001 was designed based on five major components: 1) Advisory and information services to farmers, 2) Technology development and linkages with markets, 3) Quality assurance, 4) Private sector institutional development and 5) Programme management and monitoring (Nahdy, 2002). NAADS was created to empower farmers, especially women, to demand and control agricultural advisory services in the country (Emmanuel, 2012). The expectation of NAADS was that it would operate as a decentralized system that is farmer owned and managed where privately serviced extension would be paid for by farmer-managed public funds (Opondo et al., 2006). NAADS was also expected to enhance farmers' access to quality knowledge and improved technologies through demand-driven as opposed to supply-driven delivery systems. The NAADS approach was centred on use of public funds to support advisory services while exploiting opportunities for inflow of private sector resources and a shift from public to private sector delivery of advisory services. This would in turn empower subsistence farmers to access private extension services and bring control of advisory services and research nearer to the farmers.

In terms of coordination and implementation of extension services, NAADS staff were posted in each district to run farmer groups and coordinate extension services. NAADS was coordinated through a secretariat and coordinators who oversaw the recruitment and training of Community-Based Facilitators (CBFs) that provided quick follow-up advisory services according to farmers' needs (Benin et al., 2011). The approach was that farmers willing to participate in the program join farmer groups in which they request specific technologies that they intend to implement. Farmers thereafter receive grants within the groups through which they could implement a selected technology and also obtain advisory services. A Technology Development Site (TDS), which was initially financed by the grant, would then become a source of knowledge and skills development by the farmers in the sub county.

A major shortcoming of the NAADS extension system was the lack of integration of a robust research component at the TDS, which would inform improvements in the technologies being implemented. The TDS would also have been designed in such a way that they would provide a platform for knowledge exchange as opposed to knowledge transfer (Buyinza et al., 2020a,b). Several studies have been conducted over NAADS implementation and mixed results of the program performance have been obtained. Benin et al (2011) observed improvement of extension services, farmer empowerment, better access to extension services, improved adoption of new technologies and advisory services in sub counties where NAADS had been implemented. However, they noted that weakness in financial and market sectors were major setbacks in achievement of NAADS objectives adding that NAADS had not fully addressed soil fertility management, livestock productivity and commercialization of agronomic products. A related study conducted in Soroti district in Uganda showed that farmers who were members of Farmer Field Schools and NAADS had higher use of improved soil conservation and pest management methods than non-members (Friis-Hansen et al., 2004). NAADS was also found to be top down, prescriptive, abstract, and required farmers to have high levels of literacy to make sense out of it, and the system also limited the number of enterprises (Obaa et al., 2005).

5.1.2 The Single Spine Extension System in Uganda

In 2015, the government of Uganda introduced a pluralistic approach to extension service delivery anchored to the public extension system, referred to as the single spine extension system (MAAIF, 2015, 2016) in an attempt to reform the agricultural extension system. The reforms dubbed as *"Single Spine Extension System"* included transfer of the extension function from the National Agricultural Advisory Services (NAADS) to the mainstream Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), and the creation of a Directorate of Agricultural Extension Services (DAES) in FY 2015/16. The system aims at harmonizing and coordinating all extension service delivery in the country to address the inefficiencies associated with its predecessor systems – the National Agriculture Advisory Services (NAADS) together with the single unified public agricultural extension system. One of the key tenets of the single spine system is to coordinate extension service delivery countrywide both in public and private sectors.

The single spine extension system recognizes the role played by extension managers in ensuring a successful extension system. In this regard, MAAIF developed measurable indicators to evaluate the performance of extension managers based on their roles and responsibilities (Namyenya et al., 2021). However, the new reform of the Single Spine extension service system continues to follow a top-down linear focus on extension that only encourages knowledge transfer rather than knowledge exchange through interactional approaches involving people, technologies and institutions.

5.2 Farmer Perceptions of Shaded Coffee and Management of Shade Trees Following Extension Activities

This study argues that bridging local and scientific knowledge is fundamental in enhancing agricultural technology adoption among smallholder farmers. Participatory research and extension allows integration of local and scientific knowledge while facilitating dialogue between farmers and agricultural scientists (Bicalho & Peixoto, 2017). In this study, the extension events allowed dialogue between farmers and the researcher on knowledge generated from the biophysical component of the study. Feedback from farmers (in form of perceptions towards the research outputs and willingness to adopt the recommended practices) was later obtained through the farmer survey that followed the extension activities. In the current study, while 83 out of 100 participants belonging to phase 1 project beneficiaries understood that pruning can increase coffee and common beans yield (see Table 1), only 56 farmers were fully convinced that higher coffee yields can be obtained from shaded coffee (see Table 2). This is an indication that as much as farmers may understand the message being delivered to them, it may not be convincing enough to adopt new practices by simply word of mouth, but also through other avenues such on-farm demonstrations and social networks. Indeed, several studies have demonstrated that a combination of resource constraints and socio-economic factors (Cedamon et al., 2018; Nahayo et al., 2016; Nyaga et al., 2015) as well as cognitive and psychological factors can influence agricultural technology adoption among smallholder farmers (Buyinza. et al., 2020b; Martínez-García et al., 2013).

Besides the above individual factors, information exchange and peer influences through social networks and general community interactions also provide an important angle from which to understand technology innovation adoption (Bridger & Alter, 2006; Freeman & Qin, 2020). These complex interactions are usually important at the early stages of technology adoption (Larsen, 2011) and would enable introduction of socially and biophysically appropriate agroforestry interventions into local realities. Therefore, in addition to the participatory approaches used by this study, knowledge exchange through an interactional approach involving people, technologies and institutions can be a useful approach for enhancing practice adoption in a community.

5.3 Understanding the Adoption Process among Smallholder Farmers

A better understanding of adoption among smallholder farmers calls for a systematic classification of the adoption process beyond the common binary classification (*i.e*., adoption and non-adoption). This is because technology/practice adoption is usually proceeded by a period of 'trying' and some degree of adaptation (Mwangi & Kariuki, 2015). Agroforestry adoption is a dynamic process involving farmer experimentation that occurs over a long time period with almost no immediate benefits (Kiptot et al., 2007). The Process of Agricultural Utilisation Framework (PAUF) proposed by Brown et al., (2017) goes beyond the binary classification of adoption to sub - typologies that identify different stages of a technology adoption process in a community. PAUF was initially developed to understand adoption of conservation farming technologies in eastern and southern Africa. In the current study, we apply the PAUF to understand scattered tree planting and management adoption processes and awareness of the impact of agroforestry tree management on tree water use, and yield of coffee and common bean among the four smallholder farmer categories (Table 5).

The farmer categories under the current study generally fit into the PAUF, which frames the adoption process in four phases from exposure to non-trial assessment, trial assessment and utilisation. The four phases are further divided into 10 distinct stages of the adoption process (Brown et al., 2017). While a farmer may not systematically move from stage 1 to 10, aligning the four farmer categories to the PAUF would facilitate a better understanding of the, agroforestry tree planting and management adoption pathways among smallholder farmers.

Table 5. An application of the PAUF to understand scattered tree planting and management adoption process and awareness of the impact of agroforestry tree management on tree water use, and yield of coffee and common bean among the four smallholder farmer categories

Farmer category	PAUF Adoption phase (1-4) and classification	Characteristics of farmer category in relation to PAUF and corresponding PAUF stage (1-10)
Farmer living distant and unaware of T4FS project	Phase 1 (Exposure)	These farmers have just gone through the process of sensitisation (during extension events) to obtain awareness and familiarity of canopy tree pruning and its impact of tree water use and crop productivity. These farmers would be classified as unaware prior to the extension (stage 1), they are currently aware of the practice but may be unsure of its attributes. PAUF classifies these as 'unfamiliar' at stage 2 of the adoption process.
Farmer neighbouring those actively participating in T4FS project	Phase 2 (Non-trial assessment)	These farmers have no personal experience with the practice as they have only been observing project beneficiaries. The practice could be relevant to some of them, classified as 'interested' (stage 4) and may progress to higher stages when they get involved. Those that are 'not interested' fall in the stage 3 of the adoption process.
Farmer actively participating in T4FS project from phase 2 (2017)	Phase 3 (Trial assessment)	These farmers are recent project beneficiaries undertaking trials in a confined area on their farms, entirely depending on project resources (stage 5). It is still too early for farmer driven adoption (stage 6).
Farmer actively participating in T4FS project from phase 1 (2014)	Phase 4 (Utilisation)	These farmers have been interacting with the project for a long period of time to allow adequate evaluation and implementation of the practice. The dissenting farmers are classified 'disadopters' (stage 7). While some farmers use private resources to undertake the practice (stage 8-10), majority still rely on project support (stage 5).

5.4 Impact of Development Projects on Agricultural Technology Adoption

Applying the PAUF criteria to the current study shows that the farmers actively participating in T4FS project from phase 1 (2014) are in their final stages of the adoption process (Table 5). The feedback following the extension activities also showed a better understanding of the biophysical research outputs (Table 1) and willingness to plant and prune shade trees in their coffee plantations by this farmer category. However, the majority of farmers were still relying on project support (such as free seedlings) at the time of the extension activities. In the African context, agroforestry is strongly promoted via development projects which provide incentives to farmers (Brown et al., 2017) in form of free planting materials, tree nursery inputs and capacity building on planting and management of agroforestry components (Dedefo et al., 2017; Odoi et al., 2019). This is likely to lead to 'pseudo-adoption', where the adoption claimed during implementation of a development project is not a sustained change in practice but due to the temporary influence of the existing project (Brown et al., 2017; Kiptot et al., 2007; Llewellyn & Brown, 2020).

In the current study, there is no guarantee that there will be long-term and farmer-driven adoption of shade tree planting and deliberate tree canopy pruning beyond the Trees for Food Security Project without the short-term incentives to farmers. There is also a likelihood that what appears as adoption is in fact trialling of the new practice, rendering it “pseudo adoption” (Woltering et al., 2019) and may mask whether actual long-term adoption is occurring (Llewellyn & Brown, 2020). Furthermore, the farmers could be using the practice as a strategy to access incentives from the project and may discontinue once these benefits are no longer available.

5.5 Drivers of Agricultural Technology Adoption among Africa’s Smallholder Farmers

5.5.1 Potential Adopters Recognizing the Relative Advantage of the New Practice over Existing Ones

Relative advantage is the degree to which an innovation is perceived as being better than any technology it can replace and has been reported to be an important motivation for adoption (Buyinza et al., 2021; Reimer et al., 2012). In the current study, the PAUF criteria classifies the farmers living distant and unaware of T4FS project as unfamiliar at the exposure phase of the adoption process (Table 5). Such potential adopters often have a greater need for education about the relative advantage of the new practice over the existing practices. For example, explaining that tree canopy pruning would prolong the period of intercropping would trigger mind-set change towards pruning. This is something they had not given much thought to because they have been focussing on higher yields (in short term) and less on sustained yields (over a long period of time). Highlighting the relative advantage of the practice over other existing practices (Lai, 2017; Rogers, 2003) is fundamental in motivating on-farm practice change among smallholder famers (Kuehne et al., 2017; Reimer et al., 2012).

Relative advantage is also a key component of the ADOPT framework for predicting adoption (Kuehne et al., 2017; Llewellyn & Brown, 2020), where a very high mean level of relative advantage is required for a heterogeneous community to become adopters. The current study also assessed relative advantage as one of the attitudinal measurable variables on planting and management of scattered trees on-farm on a scale of 1-7, where a high mean was registered among farmers that were directly interacting with the T4FS project (Table 4). Unlike the neighbours of project beneficiaries and those living far from the project area, farmers interacting with the T4FS project are likely to become adopters, as they perceive a coffee garden shaded with trees (which are regularly pruned) to have more general benefits than unshaded coffee. Farmers are likely to vary in their perception of a given practice’s relative advantage due to their unique set of interests influenced by economic, social and cultural (norms, beliefs) context within which the innovation will be applied (Pannell et al., 2006).

5.5.2 Existing Community Social Networks

Farmers often obtain information about new agricultural innovations from extension agents through conventional knowledge transfer extension approaches. However, several studies have established that using social networks during extension can enhance technology adoption (Beaman et al., 2015; BenYishay & Mobarak, 2019; Young, 2009). A related study involving the same farmer categories applied a multi-group structural equation modeling technique to identify differences in farmer motivations to adopting agroforestry practices in the Mt. Elgon region (Buyinza. et al., 2020a). The study found that about 40% of the variation in farmer motivation to integrate trees in their coffee plantations was explained by attitude and perceived behavioural control among farmers actively participating in the T4FS project from phase 1. In the same study, farmer motivation resulting from social pressure was strongest among farmers who had never interacted with the project, who in the absence of project interventions, relied on existing social structures to drive change in their communities.

Other related studies have also demonstrated that farmers are more likely to adopt new practices when most of their neighbours have done so, when they follow the opinion of ‘important others’ who support practice adoption, and when they are willing to gain social status in their communities (Buyinza et al., 2020b; Dessart et al., 2019). Therefore, adoption behaviour of smallholder farmers is mainly shaped by existing community social norms and beliefs that tend to promote knowledge exchange, as opposed to the conventional knowledge transfer extension approaches. Norms are therefore an inherent part of social systems and can create distinct farming practices, habits and standards within a social group. Researchers and extension agents can act upon the positive attitudes, norms and perceived behavioural controls to guarantee adoption and sustainability of agricultural technologies. Such behavioural factors can enrich economic analyses of farmer decision-making, and inform more realistic and effective smallholder agricultural technology extension policies.

5.5.3 Period and Intensity of Exposure to the Technology

The biggest impacts on agricultural technology adoption and compliance have been reported to come through direct exposure of potential adopters to the new technology and information (Ghasemiesfeh et al., 2013; Young, 2009). This is consistent with a complex contagion model of learning and technology diffusion, where multiple sources of exposure to an innovation are required before an individual adopts the change of behaviour (Beaman et al., 2015; Ghasemiesfeh et al., 2013). In the current study, the farmers interacting with the project had multiple sources of exposure to agroforestry tree planting and the impact of canopy pruning on tree water use and crop productivity through on-farm participatory trials, capacity building trainings and multiple farm visits to the biophysical experiments hosted by fellow farmers. This was not the case with their neighbours and the farmers living far from the project sites. Multiple exposure for a longer period of time (since 2014) further explains the higher mean levels of attitudinal measurable variables on agroforestry tree planting and management compared with other farmer categories (Table 4). However, there have been reported cases where a practice has been widely communicated, yet substantial levels of non-exposure and non-awareness still exist within a population (Brown et al., 2017). This may be attributed to limitations of the extension method being used in the community and limited co-learning among farmers from different cultural backgrounds and locations.

While there could be spill-over social learning by neighbours of project beneficiaries, the responses obtained from farmers living far from the project sites were based on the one-day long extension sessions with no prior exposure to the information. These farmers' prior beliefs are sufficiently strong (not to adopt shaded coffee and deliberately prune trees) that they typically require multiple observations to adjust their priors and induce adoption. With this minimum level of exposure, such farmers can only learn whether to adopt shaded coffee or not but not necessarily how best to plant and manage the trees.

6. Conclusion

Low agricultural technology adoption continues to hold large productivity, sustainability and resilience consequences for majority of farmers in developing countries. However, several cases have been reported in Africa where farmers have been hesitant to adopt well-researched innovations (Van Loon et al., 2020; Uguru et al., 2015; Kiptot et al., 2007). This study drew upon knowledge generated from a biophysical experiment to assess changes in farmers' perceptions after exposure to information on agroforestry tree planting and management in coffee-bean systems in the Mt. Elgon region of Uganda. While farmers may understand the information delivered through different knowledge transfer approaches, they may not actually be convinced enough to adopt new practices as other factors may come into play. Although a combination of resource constraints, socio-economic and psychological barriers can be minimized by bridging local and scientific knowledge, a better understanding of the adoption process calls for a systematic classification of the adoption beyond the common binary classification. We applied the Process of Agricultural Utilisation Framework (PAUF) proposed by Brown et al., (2017) to understand scattered tree planting and management adoption process and awareness of the impact of agroforestry tree management on tree water use, and yield of coffee and common bean among four smallholder farmer categories.

In the African context, agroforestry is strongly promoted via development projects that provide incentives to farmers in form of free planting materials, tree nursery inputs and capacity building on planting and management of agroforestry components. In the current study, there is a likelihood that what appears as adoption is in fact trialling of the new practice, which masks actual long-term adoption. The project beneficiaries could be using the practice as a strategy to access incentives from the project and may discontinue once these benefits are no longer available. We therefore suggest that adoption information exchange and peer influences through social networks and general community interactions (e.g through farmer-to-farmer extension approaches) provide an important angle from which to understand technology innovation adoption. These complex interactions are usually important at the early stages of technology adoption and would facilitate introduction of socially and biophysically appropriate agroforestry interventions into local realities. The study has generally demonstrated that adoption is not merely related to the technology, socio economic and behavioural factors, and the research and extension methods applied, but also a result of complex interactions between people, technologies and institutions.

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Appendix A

Table A: Analysis of variance on farmer opinion on crop combinations and tree management options

Variables on crop and tree management options		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Unpruned Cordia + coffee + beans	Between Groups	5.795	3	1.932	1.450	0.245
	Within Groups	45.284	34	1.332		
	Total	51.079	37			
Pruned Cordia + coffee + beans	Between Groups	78.405	3	26.135	19.332	0.000**
	Within Groups	454.239	336	1.352		
	Total	532.644	339			
Unpruned Albizia + coffee + beans	Between Groups	21.069	3	7.023	3.386	0.024*
	Within Groups	126.531	61	2.074		
	Total	147.600	64			
Pruned Albizia + coffee + beans	Between Groups	10.935	3	3.645	2.704	0.045*
	Within Groups	465.065	345	1.348		
	Total	476.000	348			
Coffee only but under unpruned Albizia	Between Groups	14.388	3	4.796	3.334	0.024*
	Within Groups	112.210	78	1.439		
	Total	126.598	81			
Coffee only but under pruned Albizia	Between Groups	5.092	3	1.697	1.132	0.336
	Within Groups	500.959	334	1.500		
	Total	506.050	337			
Coffee only but under unpruned Cordia	Between Groups	3.177	3	1.059	.953	0.422
	Within Groups	55.582	50	1.112		
	Total	58.759	53			
Coffee only but under pruned Cordia	Between Groups	4.711	3	1.570	1.252	0.291
	Within Groups	385.192	307	1.255		
	Total	389.904	310			
Unshaded coffee	Between Groups	4.771	3	1.590	.711	0.555
	Within Groups	53.657	24	2.236		
	Total	58.429	27			
Beans in open field	Between Groups	41.668	3	13.889	7.356	0.000**
	Within Groups	417.292	221	1.888		
	Total	458.960	224			
Beans + Unshaded coffee	Between Groups	9.447	3	3.149	1.487	0.221
	Within Groups	281.692	133	2.118		
	Total	291.139	136			

**significant at 5% significance level; **significant at 1% significance level*

Appendix B

Posters used during extension events

Figure B1. A poster on impact of pruning on productivity of coffee and common beans (English version)

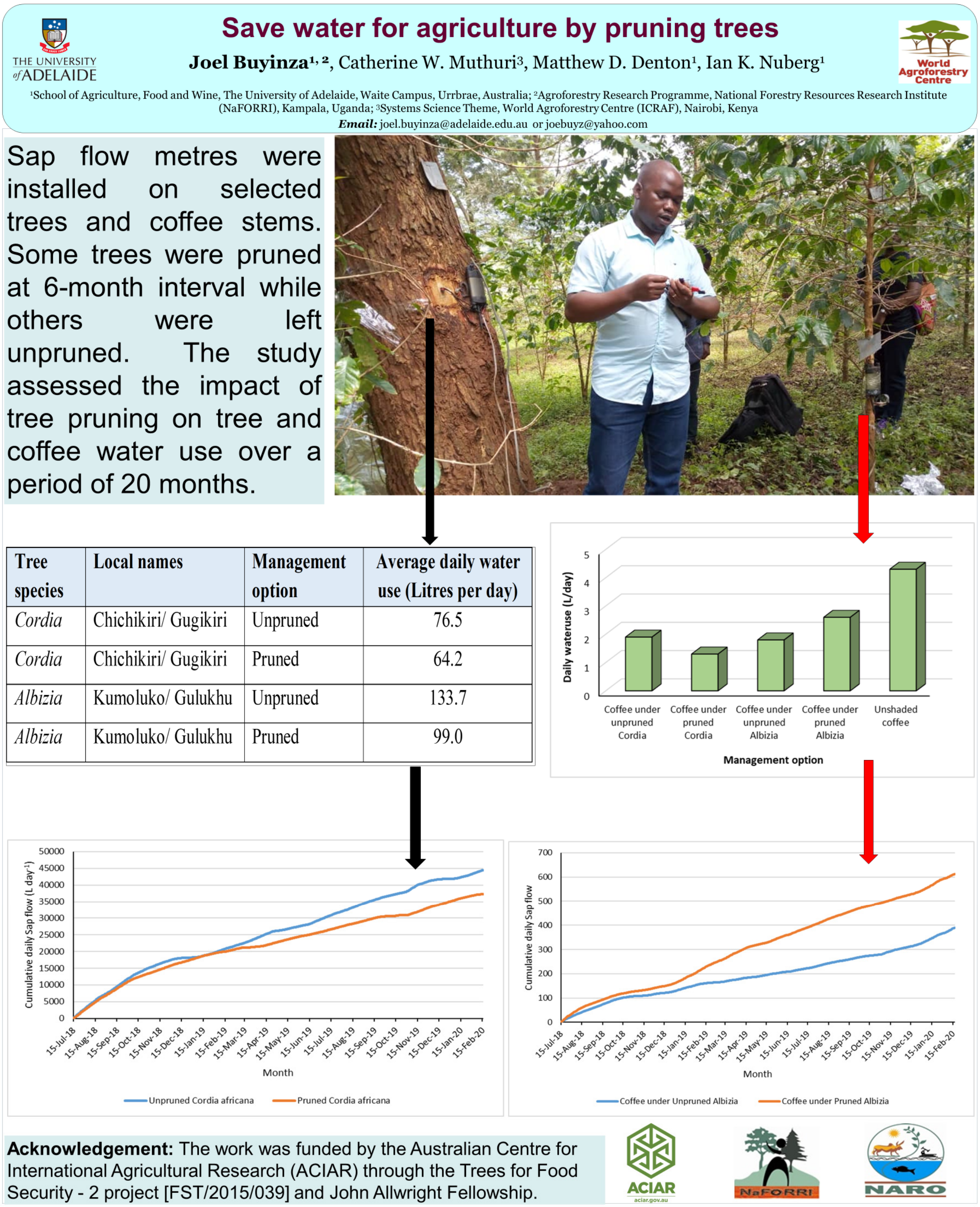

Figure B2. A poster on impact of pruning on tree and coffee water use in smallholder farming systems (English version)

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