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Influence of Socio-Technological Factors on Smallholder Farmers' Choices of Agroforestry Technologies in the Eastern Highlands of Uganda

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Abstract
In Sub-Saharan Africa, agroforestry has been identified as the most sustainable remedy to counter declining farm productivity. Over the last decades, researchers and other actors have promoted several agroforestry technologies to improve farm productivity. Sometimes, the promotion message provided through extension assumes a homogenous smallholder farmers' context. However, smallholder farmers' social and farm contexts are heterogeneous. Smallholder farmers make different choices of which technologies fit their contexts. A range of factor categories influence and (re)shape choice decisions of smallholder farmers. In this paper, the authors seek to articulate the importance of socio-technological factors shaping smallholder farmers' choices of specific agroforestry technologies on their farms. Knowledge of these factors provides insights that inform the design of refined farmer context-based extension messages, consequently enhancing the scaling-up of agroforestry technologies. The Decomposed Theory of Planned Behaviour was used as the main framework to understand smallholder farmers' choice decisions among agroforestry technologies. We used a mixed methods approach. Quantitative data were collected from 277 randomly selected farming households in the eastern highlands of Uganda. Qualitative data that complemented the quantitative were collected using focus group discussions. An alternative-specific conditional logit model was used to model smallholder farmers' agroforestry choices. Results indicated that the number of tree species desired by the farmer and the perceived value of the technology were the most critical factors that commonly influence smallholder farmers' choice of agroforestry technologies. The influence of other factors such as gender, the number of training sessions attended, total land owned, peer influence and perceived behavioural control were technology-specific, suggesting the need to tailor agroforestry interventions to specific farmer categories.

Keywords Choice decisions · Farm productivity · Conditional logit · Focus groups · Decomposed theory

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Introduction

The declining trend of farm productivity among smallholder farmers in Sub-Saharan Africa is a significant concern. Factors attributed to this trend include soil erosion, land degradation and unsustainable farming practices (Sheahan and Barrett 2014). These factors' impacts are worsened by climatic risks such as drought, flooding, landslides/mudslides, pests and diseases, that have become more prevalent (Bomuhangi et al. 2016; Mubangizi et al. 2017). Agroforestry is promoted among smallholder farmers as one of the promising remedies to counter these challenges. Agroforestry is defined differently by different scholars. According to Nair (1993), agroforestry is a collective name for land-use systems and practices in which trees are deliberately integrated with crops and/or animals on the same land management unit in a spatial or temporal arrangement. Most recently, van Noordwijk et al. (2016) defined agroforestry as a practice and science of the interface and interactions between agriculture and forestry, involving farmers, crops, livestock and forests/trees at multiple scales. This recent definition includes trees that are not necessarily planted but deliberately retained in agricultural landscapes. In the context of this study, the emphasis is given to trees that are deliberately planted with crops or animals in a spatial or temporal arrangement to supplement farm productivity by enhancing soil fertility, reducing soil erosion, diversifying farm products or sustaining yields (Luedeling et al. 2016; Coulibaly et al. 2017; Rahn et al. 2018).

Frequent mismatches have been observed between technologies introduced and smallholder farmers' needs, who have to make complex decisions in allocating limited resources (Ssebaggala et al. 2017). These mismatches are common, especially where the generation of technology and its subsequent introduction to smallholder farmers follow a top-down approach (Iiyama et al. 2018). Under the top-down approach, smallholder farmers should have many alternatives to choose what suits their contexts. To help smallholder farmers integrate trees on their farms for increased productivity, experts have devised several agroforestry technologies including woodlots, fodder-banks, intercropping, boundary planting, alley cropping, improved fallows, among others (Sinclair 1999; Luedeling et al. 2016). Some may argue that these are not new technologies since farmers have long been integrating trees on their farms in ways that mirror these technologies (Lamond et al. 2016). However, they translate into technologies since they are characterised by specific tree species, their spatial and temporal arrangement, establishment and spacing, as well as management aspects that are unique from what farmers are used to (Von Carlowitz 1989; Gram et al. 2017). Positive outcomes have been realised where smallholder farmers have chosen agroforestry technologies that suit their contexts. In Ethiopia, for example, woodlots were found to maximise farm productivity and smallholder farmers' incomes (Kassie 2016). This study focuses on three agroforestry technologies (boundary planting, intercropping and woodlot) which are dominant agroforestry practices in the eastern highlands of Uganda.

Several factors broadly categorised into socio-economic, institutional, technological and human-specific factors are known to influence smallholder farmers' choice decisions about what new technologies to take up (Mwangi and Kariuki 2015). Technologies get introduced into a social system, and factors influencing choice often come up due to the interactions of the social (human) and technical domains of the technology, hence the term "socio-technological factors" used in this study. The interaction between the potential users' social characteristics and the attributes of a technology influence choice decisions made by the ultimate user (Zubair and Garforth 2006; Mignouna et al. 2011; Wandji et al. 2012; Mwangi and Kariuki 2015). Studies to examine the influence of socio-technological factors on choice decisions remain scant in the agroforestry literature. McGinty et al. (2008) found that perceived behavioural control and attitudes about conservation contributed significantly to the intention to adopt or maintain agroforestry in Brazil. In a study that focused on on-farm plantation forestry in Uganda, Kiyingi et al. (2016) found that landholdings, education, skills training, and farmers' perceptions significantly explained smallholders farmers' variation in their choice decisions to invest in on-farm plantation forestry. Studies like these have either focused on agroforestry in general or a single technology. Yet, smallholder farmers often face a range of technologies and must choose those that suit their contexts. Moreover, information on the extent to which smallholder farmers' socio-technological contexts explain the agroforestry technologies on their farms is unknown.

Therefore, this study's objective was to generate information that would guide the development of context-based extension messages to promote the scaling-up of appropriate agroforestry technologies in the eastern highlands of Uganda. If agroforestry technologies are to be taken up to scale for the advantage of improving farm productivity, agroforestry promoters and policy makers must tailor their interventions towards specific smallholder farmers' categories. Specifically, the study aims to: (1) describe the predominant agroforestry technologies; and (2) determine the extent to which smallholder farmers' socio-technological contexts explain their choice of agroforestry technologies. This study contributes to the literature in three-fold: (1) the study applies the Decomposed Theory of Planned Behaviour (DTPB) and demonstrates that it offers a structured framework for understanding smallholder farmers' choice decisions of agroforestry technologies in a developing country context; (2) This study applies an alternative-specific conditional logit (ASCLOGIT) model to examine the extent to which smallholder farmers' socio-technological context explain their choices of agroforestry technologies; and (3) the work underpins the importance of understanding smallholder farmers' socio-technological contexts in designing and implementing interventions aimed at scaling-up agroforestry technologies.

Theoretical Framework

Over the decades, several theoretical models have been proposed and used to understand people's behaviour. One of the most known is the Theory of Planned Behavior (TPB) (Ajzen 1991), which has been applied in many contexts, including agriculture (Borges et al. 2014; Wauters et al. 2010). TPB postulates that behavioural intentions are determined by attitudes, subjective norms and perceived behavioural control. TPB has, however, come under criticism for its treatment of attitude as a unidimensional construct. Treating the cognitive components of attitude as a single construct does not provide an accurate understanding of behavioural intentions (Taylor and Todd 1995a; Moons and De Pelsmacker 2015). Based on a comprehensive review and synthesis of several theoretical models, Taylor and Todd (1995a) proposed the Decomposed Theory of Planned Behaviour (DTPB), which has since been applied widely to understand technological choice decisions in a variety of fields, including agriculture (Gangwal and Bansal 2016; Aziz and Afaq 2018; Md Husin and Ab Rahman 2016; Zahid and Din 2019).

Drawing from the Innovation Diffusion Theory (Rogers 1983), Taylor and Todd (1995a) decomposed attitude into three constructs to provide a way of understanding behavioural intentions (Kyere-Duodu and Yamoah 2011): perceived value of the behaviour, perceived ease of use of the behaviour and perceived compatibility of the behaviour. The perceived value of the behaviour is one's evaluation of its merits and ability to meet their needs and expectations; perceived ease of use is a measure of how easy the person can apply a behaviour; and compatibility of the behaviour is the degree to which a behaviour is perceived as consistent with existing practices. DTPB retains the other two constructs as applied by TPB, i.e. subjective norms—which describes the extent to which one is influenced by the views of other people or groups of people regarding the behaviour; and perceived behavioural control—which refers to one's perception of their ability (e.g. having the necessary resources and opportunities) to perform a given behaviour. This study applied DTPB (Taylor and Todd 1995a) as a framework to examine smallholder farmer choice decisions among agroforestry technologies. The argument is that our empirical study deals with agroforestry technological innovations, and thus DTPB gives a satisfactory explanation of choice decisions. Also, DTPB is applicable in a variety of situations, has high explanatory power in explaining behaviour, allows for the decomposition of belief variables, and is flexible enough for the incorporation of other explanatory variables (Taylor and Todd 1995b; Hernandez and Mazzon 2006; Kyere-Duodu and Yamoah 2011). In the context of this study, smallholder farmer's choice decision and continued usage of the agroforestry technology mirrors the behavioural intention and actual behaviour as applied in DTPB.

Based on DTPB and in the context of this study, farmers would be more likely to choose an agroforestry technology when they perceive it to be easy to apply, consistent with existing practices and offer more benefits (Zubair and Garforth 2006; Mignouna et al. 2011; Moons and De Pelsmacker 2015; Mwangi and Kariuki 2015). Likewise, an agroforestry technology that carries positive opinion of other people, especially those close to the potential user (peers), would be perceived positively and thus more likely to be chosen by smallholder farmers (Aziz and Afaq 2018; Zahid and Din 2019). Besides, a smallholder farmer's positive evaluation of his/her ability to use the new agroforestry technology, i.e. the conviction that one has the necessary resources (both material and non-material), would increase the likelihood of it being chosen (McGinty et al. 2008; Zahid and Din 2019). The word 'perceived' as used in DTPB applied well in the context of this study, given that agroforestry is a long-term enterprise, and most smallholder farmers in the study area had not fully realised the intended benefits. In the context of this study, other factors that are hypothesised to influence choice decisions of technologies are considered, including gender (referring to male or female), membership to a farmer group (here referred to as a group of farmers with an element of cooperative action on any agricultural activity), off-farm income, marital status, agroforestry training sessions attended, number of tree species that can be incorporated using technology, and size of land available for technology implementation (Mignouna et al. 2011; Kiyingi et al. 2016; Sanou et al. 2017; Kutia et al. 2019).

Methodology

Study Area and Sampling

The study was conducted in the eastern highlands of Uganda (Fig. 1), an area with a decline in productivity of once very fertile and productive volcanic soils. Manafwa and Namisindwa were the study districts selected because of ongoing research and development efforts to demonstrate the importance of trees in agricultural landscapes; a dense population, estimated at 900 persons per square kilometre (UNEP 2014) that has resulted in the subdivision of once large farms into small landholdings along lineages; and a community reportedly receptive towards embracing

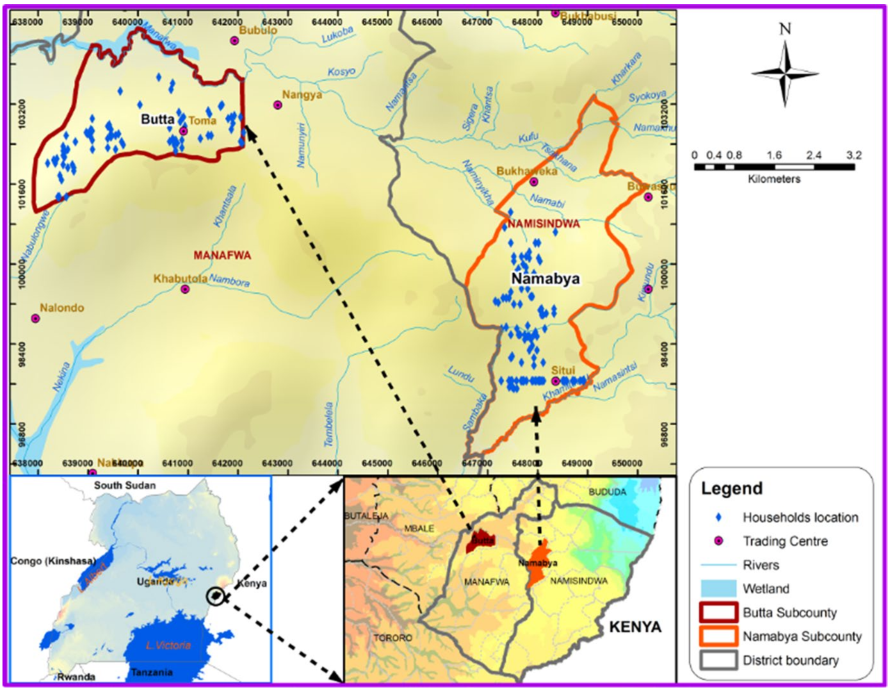

Fig. 1 Map showing study sites and distribution of the sampled households

agroforestry technologies (Barrios and Coe 2014). The districts form part of the Trees for Food Security (T4FS) project sites—an Australian Centre for International Agricultural Research (ACIAR) funded project which aims at improving household food security and smallholder livelihoods through widespread adoption of appropriate agroforestry technologies. Currently, in its second phase, the T4FS project is being implemented by the World Agroforestry Centre (ICRAF) in partnership with the National Agricultural Research Organisation (NARO), World Vision Uganda and Makerere University. The T4FS project provides agroforestry training and free tree seedlings to smallholder farmers to integrate trees into agricultural landscapes. In consultation with key informants in each district (district environmental officer, district agricultural extension workers and T4FS project staff), one sub-county with high densities of smallholder agroforestry farms was purposively selected from each district. From the selected sub-counties (Butta in Manafwa and Namabya in Namisindwa), the 1,011 households that participated in agroforestry training sessions and received tree seedlings were the population of our sampling. Sub-county officials (community development officers, agricultural extension workers and trees for food security project staff) knew the households that fell in this category and generated the list. Simple random sampling was used to select a sample of 277 smallholder farming households to participate in the cross-sectional survey following Krejcie and Morgan (1970).

Data Collection Methods Used

This study employed a cross-sectional survey to elicit data on smallholder farmers' choices of agroforestry technologies and the rationale for their choice decisions. To ensure mutual exclusivity among choices of agroforestry technologies, given that sometimes smallholder farmers chose more than one alternative, the most predominant option (guided by smallholder farmers' preferences and on-farm observations) was considered. Before conducting the survey, a structured questionnaire was prepared and pre-tested with 20 smallholder farmers. The pre-testing was useful to improve the flow and clarity of questions. The final version of the questionnaire consisted of three sections: farm and household characteristics, smallholder farmers' description of the agroforestry technologies, and questions based on DTPB. Because the study involved constructs (here referred to as latent variables) that could not be accurately measured with a single question, proxy variables were generated. Proxy variables were formulated into statements (Table 1) for which data was collected using a five-point Likert scale (with 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree).

Data on demographic and socio-economic variables such as gender, age, level of education, household size, household land size, membership to farmer groups, off-farm income and number of agroforestry training sessions attended during the last two years were also collected. We mainly interviewed the household head, who, by default, is more knowledgeable about the decisions on the farm than other household members. Survey data were collected through face-to-face interviews with the

Table 1 Proxies transformed into statements for collecting data about latent variables

The perceived value of the technology
The technology is suitable for planting trees that would provide herbal medicine
The technology is suitable for planting trees for increasing firewood availability in the household
The technology is suitable for planting trees that would increase household income
The technology is suitable for planting trees that are an essential source of food (fruits) to the household
The technology is suitable for planting trees that can provide fodder for my animals
The technology enables me to plant trees that can provide shade to crops
The use of agroforestry technology would help me to make use of degraded/unproductive sites on my farm
The technology would enable me to plant trees that would improve soil fertility on my farm
The technology allows me to plant trees that provide building materials for domestic structures
Perceived ease of use of the technology
The use of agroforestry technology does not require a lot of technical knowledge
There was no need for prior experience to use the agroforestry technology
The agroforestry practice did not require much labour to be implemented
Compatibility with other components on the farm
Implementing the agroforestry technology did not necessitate me to rearrange the existing enterprises
The agroforestry technology suits my household farming objectives
The agroforestry technology enables me to use tree species that have no direct effect on existing crops
The agroforestry technology is appropriate to the landscape location of the farm
Peer influence (subjective norms)
I was influenced by the researchers (e.g. NARO, MAK, ICRAF) to use the agroforestry practice
I was influenced by the extension workers (local government) to use the agroforestry practice
The presence of other farmers who were already using the agroforestry technology influenced me to use it
I was influenced to use agroforestry technology because many Non-Government Organisations (NGOs) were promoting it in the area
Many Community-Based Organisations (CBOs) operating in the area influenced me to use the agroforestry technology
Perceived behavioural control
Technical information received about the agroforestry technology was sufficient
Seedlings for tree species that are needed to implement the agroforestry technology are readily available
My previous experience in tree growing matched the agroforestry technology
The agroforestry technology was appropriate to the size of land we have
We have enough labour needed to implement the agroforestry technology
My choice of agroforestry technology was based on my determination and confidence in my abilities to implement it

help of five enumerators. Each interview took about 2 h to be completed. Data collection took place from February to March 2019.

Six focus group discussions (FGDs) were conducted; three before the survey and three afterwards. In general, three focus group discussions were conducted in each sub-county. The three FGDs conducted before the survey aimed at describing the agroforestry technologies in terms of: how they were being understood and hence utilised by the smallholder farmers, the common tree species used, and the role and output from the trees. The two focus groups conducted after the survey were intended to generate qualitative data, which was needed to explain some of the survey findings. A total of 54 farmers (31 males and 23 females) who constituted the six focus groups were purposively selected based on their age (above 35 years), gender (male or female) and having at least one of the three agroforestry technologies. Smallholder farmers over 35 years were preferred because of their presumed experience in farming. On average, each focus group discussion consisted of 9 participants and lasted about two hours. Each attendee participated only in one focus group. Two moderators conducted the FGDs—one acting as a facilitator to guide the discussions and the other as an assistant documenting (notetaking) the detailed content of the discussion. All FGDs were audio-recorded as a backup using a digital voice recorder, with the consent of all participants.

Ethical Considerations

Before commencement of the study, an introductory letter was obtained from the Department of Extension and Innovation Studies, Makerere University. The letter introduced the research team to the relevant district and sub-county local council leaders who permitted us to conduct the focus group discussions and interviews in the communities. Also, we sought voluntary informed consent from the participants to capture field notes, photographs and audio recording (where applicable).

Data Analysis

The notes from the FGDs were refined using audio recordings to include as much detail as possible and ensure that the information accurately reflected the content of the discussion. Data were reduced and organised into themes to describe the predominant agroforestry technology or explain quantitative findings from the survey.

Quantitative data from the survey were summarized into percentages, means and standard deviations to describe the smallholder farmers' profiles. Inferential statistics were used to analyse the relationships between variables and determine the extent to which smallholder farmers' socio-technological contexts influenced their choice of agroforestry technologies. STATA software version 13.0 was used to run the descriptive statistics and the alternative specific conditional logit (ASCLOGIT) model.

Empirical Model

Exploratory factor analysis was used to generate the indices for the latent variables used in the model. The Kaiser-Mayor-Oklin measures of sampling adequacy (KMO) and Bartlett's Test of Sphericity which relates to the validity and suitability of responses, were used with thresholds of > 0.5 and ≤ 0.05 respectively to check for suitability of data for factor analysis (Field 2009). All factors with Eigenvalues of more than one were considered. Following Keil et al. (2008) and Banda et al. (2016), the first factor which extracted the highest variance was used as the proxy measure for the latent variable. The explanatory variables used for model estimation were mainly drawn from the literature on technological choice decisions in developing countries. To determine the multicollinearity between independent variables, collinearity diagnostic tests were done using the Variance Inflation Factor (VIF) values (at a threshold of VIF ≤ 5.00). Only non-collinear variables were included in model estimation to avoid getting biased estimates emanating from multicollinearity.

A farmer selected a predominant agroforestry practice from three alternatives: boundary planting, intercropping and woodlot. As such, the dependent variable in the model is categorical, unordered, and polytomous. Given this setup, an unordered utility model motivated by the random utility was preferred for the analytical framework. Smallholder farmers would choose alternative j if the utility from that alternative was higher than the utility from any other alternatives. Therefore, the probability for a specific choice is given by:

$$P_{ij} = \frac{\exp\left(X_{ij}\beta\right)}{\sum_{j=1}^{J} exp\left(X_{ij}\beta\right)} \quad for\ i = 1, \dots, I\ and\ j = 1, \dots, J \tag{1}$$

where x_{ij} denotes a row vector of observations on variables of interest for respondent i and alternative j and β is a vector of parameters, usually different for each $j = 1, \dots, J$.

The survey data in this analysis include both case-specific and alternative specific explanatory variables. Case-specific variables vary only across cases/respondents (e.g., gender, age, etc.), while alternative-specific variables vary across both cases/respondents and alternatives/choices (e.g. the number of tree species desired by the farmer in each technology and land size required for each technology) (Cameron and Trivedi 2005). Given this nature of the explanatory variables, the Alternative-Specific Conditional Logit (ASCLOGIT) model (Mcfadden 1977) was chosen over the multinomial logit to determine the influence of socio-technological factors on farmers' choice of agroforestry technologies (Cameron and Trivedi 2005; Greene 2012; Tanellari et al. 2015). When some of the regressors are alternative-specific, Eq. (1) becomes:

$$P_{ij} = \frac{\exp\left(X'_{ij}\beta + Z'_{i}Y\right)}{\sum_{J=1}^{j} \exp\left(X'_{ij}\beta + Z'_{i}Y\right)} \quad for\ i = 1, \dots, I\ and\ j = 1, \dots, J \tag{2}$$

where x_{ij} are case-specific regressors, z_i are alternative-specific regressors and β, and y are vectors of parameters.

The estimation of the ASCLOGIT model was undertaken by setting the intercropping category as the base alternative because it was the most preferred alternative (Mcfadden 1977; Greene 2012). Marginal effects were used to determine the probability of choosing a given practice for a unit change in the predictor variable or a change from 0 to 1 in the case of discrete variables.

Results and Discussions

Socio-Economic and Demographic Characteristics of the Farmers

The majority (59%) of the respondents were males (Table 2) because, within the sampled households, we targeted to interview household heads. It is common in such a patriarchal community in the area of study for men to be considered household heads even when this does not mean that they are the overall decision-makers in the households. The result indicates that 43% of the respondents were engaged in off-farm income-generating activities, with the most common activities being brickmaking, trading, carpentry, construction, fishing and food vending. The proportion of smallholder farmers involved in off-farm income-generating activities indicates that households in the area are strongly dependent on agriculture, and farm productivity declines threaten their livelihoods. The proportion of smallholder farmers who were members of farmer groups was 32%, higher than the 18% reported in the region (Mwaura 2014). Considering that civil society organisations and government generally adopt the farmer group approach, most farmers may not access the desired information if the same model is applied in agroforestry extension. Most of the respondents (91%) were married, with formal and informal marriages considered in this study. Most of the smallholder farmers were married because high social importance is attached to marriage among the Bamasaba (the predominant tribe in the study area)—with families arranging traditional marriages for their children. The average age of the smallholder farmers was 46 years. They spent, on average, about

Table 2 Smallholder farmers' socio-economic and demographic characteristics

Characteristic	Percentage (n = 277)	Mean (SD) (n = 277)
Gender		
Male	58.8	
Female	41.2	
Off-farm income		
Yes	43.3	
No	56.7	
Group membership		
Yes	31.8	
No	68.2	
Marital status		
Married	91.3	
Unmarried	8.7	
Age of the respondent		46.5 (13.0)
Years spent in school		7.1 (3.7)
Total land owned		3.7 (3.0)
Number of agroforestry training sessions attended		2.2 (1.2)
Number of tree species		4.2 (2.1)

seven years in school which translates to having at least the basic literacy skills necessary to interpret most of the extension messages. The average land size was about 3.7 (acres). This land size is larger than the 2 (acres) reported in the region (Mubangizi et al. 2018), possibly because this study targeted agroforestry farmers who could have had slightly more land that could have served as an incentive to take up some of the agroforestry technologies (Mubangizi et al. 2017). On average, smallholder farmers attended about two agroforestry training sessions and had about four tree species on their farms.

Description of the Predominant Agroforestry Technologies

Smallholder farmers' understanding of agroforestry technologies differs from that of the experts because it depends on the local context that varies among farming households. Their knowledge of agroforestry will likely form the basis of their attitude, thereby influencing how the agroforestry technologies are taken up locally and what their actual impacts are on the ground. Thus, a need to understand smallholder farmers' contextual description of agroforestry. The three predominant agroforestry technologies (identified during the pre-study) in Uganda's eastern highlands were discussed with smallholder farmers in focus groups. The woody perennial (tree) forms the common denominator in all the agroforestry technologies (Nair 1993). We summarized the detailed information elicited from the focus group discussions according to the tree component's arrangement, role and function, followed by the predominant crop enterprises and common tree species (Table 3). A brief description of each agroforestry technology is highlighted below.

Boundary planting: According to the FGD participants, trees could be planted on the edges of plots either systematically or randomly for protective functions, e.g. windbreak and soil erosion control; productive functions such as firewood and timber; and cultural functions such as the demarcation of plot boundaries. The most commonly used tree species under boundary planting were *Neolamarckia cadamba, Grevillea robusta, Markhamia lutea* and *Calliandra calothyrsus*. *Markhamia lutea* was mainly nurtured from wildings, while seedlings were often distributed by the T4FS project for the rest of the tree species. Tree species used under boundary planting were preferred for their fast-growing and adaptability to harsh conditions experienced at the boundaries, mainly due to grazing animals such as goats and cows. While trees on the boundary offer several products and services, they can also reduce adjacent crops' productivity and generate conflicts with neighbours (Bala et al. 2020; Sassen et al. 2013). Therefore, appropriate trees and their management should be carefully considered for boundary planting agroforestry technology.

Intercropping: In this technology, FGD participants reported that trees are integrated with food crops whether randomly or systematically for tree products (e.g. firewood, fruits, medicine) and protective functions (e.g. soil fertility) and services (soil fertility, shade) as desired by the smallholder farmers. The tree species were mainly intercropped with perennial crops (coffee and/or banana). Common tree species included indigenous ones such as *Albizzia coriaria* and *Cordia africana* (used primarily for soil fertility and shade) and exotic ones—mainly fruit trees such as

Table 3 Description of the main agroforestry technologies

Criteria	Boundary planting	Intercropping	Woodlot
Establishment and spacing	Trees planted systematically on edges of plots Spacing varies from 2 to 10 m	Trees integrated into crop fields Often wide spacing of up to 15 m to reduce competition with crops	Single tree species or a mixture established in an area entirely set aside for tree growing Spacing can be as close as 0.5 × 0.5 m
Role and output from the trees	Demarcation, windbreak, soil conservation, boundary marking, firewood, fodder, timber, fruits	Fruits, fuelwood, wood, herbal medicine, soil improvement, shade	Landscape rehabilitation, firewood, timber, poles
Predominant crop enterprises	Annual crops such as maize, beans, soybeans, potatoes, cassava	Perennial crops such as bananas, coffee	Annual crops such as yams and beans
Common tree species	Exotic: *Neolamarckia cadamba* Roxb, *Grevillea robusta* A.Cunn. ex R.Br., *Calliandra calothyrsus* Meisn Indigenous: *Markhamia lutea* (Benth.) K. Schum	Indigenous: *Albizzia coriaria* Welw., *Cordia africana* Lam Exotic: fruit trees such as *Persea americana* Mill., *Mangifera indica* L.	*Exotic: Eucalyptus* spp., *Grevillea* robusta A.Cunn. ex R.Br., *Neolamarckia cadamba* Roxb

Persea americana (avocado) and *Mangifera indica* (mango) (mainly used for fruits). FGD participants mentioned three major environmental benefits of the intercropping technology in descending order: cropping fields with trees are less likely to be severely affected by drought, trees help to replenish soil fertility and control soil erosion. This agrees with studies showing that trees integrated with crops provide many environmental services (Dai et al. 2017; Kuyah et al. 2016). Studies show that both *A. coriaria* and *C. africana* have been found by farmers to be highly favourable when planted with crops like banana and coffee and are recognized for adding nutrients to the soil (Bukomeko et al. 2018; Gram et al. 2017; Kalanzi and Nansereko 2015). FGD participants noted that smallholder farmers integrated fruit tree species such as *M. indica* and *P. americana* for food and income security. However, they also pointed out that these fruit trees are highly competitive with crops because of their large and dense crowns. Studies have also found out that most fruit trees, including *M. indica* and *P. americana*, are not suitable in crop fields because of their dense shade intensity, although smallholder farmers prefer them for their direct contribution to household food security (Kalanzi and Nansereko 2015; Zubair and Garforth 2006). During the FGDs, smallholder farmers also added that integrating fruit trees in crop fields instead of planting them at the boundary is a way of securing fruits. Thieves find it harder to enter people's gardens.

Woodlot: Participants in the FGDs described a woodlot as a single or multiple tree species established usually on a less productive plot, mainly for firewood, poles or timber. During the FGDs, farmers expressed that *Eucalyptus* spp. were the most used in the woodlot, followed by *Grevillea robusta* and *Neolamarckia cadamba*. In the early stages of the woodlot, before trees close their canopies, smallholder farmers sometimes integrated annual crops, mainly yams and beans. FGD participants argued that they could only establish woodlots on plots unsuitable for crop cultivation, such as rocky or waterlogged plots. Such plots would otherwise remain unused or less productive to the household. In both rocky and waterlogged areas, eucalyptus was mentioned by the participants as the most adaptable tree species. Eucalyptus trees grow straight and have a smaller canopy, thus needing less space than other tree species. The ability to sprout was also mentioned by participants as a desirable characteristic of Eucalyptus. Therefore, Eucalyptus was preferred because it could sustain the production of firewood, poles, and timber—products that were highly demanded in local markets in the eastern highlands of Uganda (Gram et al. 2017).

Creating Indices for the Latent Variables

Table 4 shows the number of factors from which indices for the latent variables were derived. Three factors accounting for 52.9% of the variance were extracted for the perceived value of the technology. One factor which accounted for 44.3% of the variance was retained for ease of use of the technology. Two factors accounting for 59.1% of the variance were extracted for perceived compatibility with existing practices. Two factors accounting for 50.8% were retained for peer influence. Finally, three factors were retained for perceived behavioural control, accounting for 58.9% of the variance. In this study, the factor-score for the factor which extracted the

Table 4 Principal factors retained during the estimation of indices for the latent variables

Behavioural variable	KMO	Bartlett's test of Sphericity	Factor	Actual eigenvalue	% of variance explained	Cumulative %
Perceived value of the technology	0.647	0.000	1	2.43	27.0	27.0
			2	1.29	14.3	41.3
			3	1.042	11.6	52.9
Ease of use	0.559	0.000	1	1.33	44.3	44.3
Perceived compatibility	0.538	0.02	1	1.304	32.6	32.6
			2	1.06	26.5	59.1
Peer influence	0.569	0.000	1	1.501	30.0	30.0
			2	1.039	20.8	50.8
Perceived Behavioral Control	0.565	0.001	1	1.444	24.1	24.1
			2	1.082	18.0	42.1
			3	1.011	16.8	58.9

Extraction method: principal component analysis and rotation method: varimax with Kaiser normalization

highest variance was used as the generated index for the latent variable (Keil et al. 2008; Banda et al. 2016). Latent variables were then used in the model estimation.

Socio-Technological Factors Influencing Farmers' Choice of Agroforestry Technologies

The estimation of the ASCLOGIT model had a Wald Chi-square of 59.37, which was highly significant ($p < 0.01$), suggesting that the chosen explanatory variables fitted the model reasonably well. The Pseudo R^2 (0.26) fell between 0.2 and 0.4, indicating a very good model fit (Mcfadden 1977).

The marginal effects of the ASCLOGIT model presented in Table 5 indicate the impact that each socio-technological factor had on the choice decision of agroforestry technologies holding all other factors constant. The number of tree species desired by the farmer in each technology, together with the perceived value of the technology, were the most critical factors significantly and positively related to the choice decision of an agroforestry technology. The effect of other socio-technological factors varied with technology.

A one-unit increase in the number of tree species a smallholder farmer desires to plant in each agroforestry technology increases the probability of the technology being selected. The highest effect occurs in the intercropping technology (3.3 percentage points), followed by boundary planting (2.7 percentage points) and, lastly, woodlot (2.1 percentage points). The high effect is because smallholder farmers have several needs, including fruits, poles, timber, firewood, soil conservation and shade. Even a multipurpose tree species may not offer all the anticipated benefits of the farmer (Gram et al. 2017). Therefore, smallholder farmers who are constrained by land in the first place will prefer to choose an agroforestry technology where

Table 5 Influence of socio-technological factors on farmers' choice of agroforestry technology

Variable	Boundary planting	Intercropping	Woodlot
Alternative-specific			
Number of tree species in boundary planting	0.027***	– 0.014**	– 0.003***
Number of tree species in intercropping	– 0.003**	0.033***	– 0.018***
Number of tree species in woodlot	– 0.014***	– 0.018***	0.021***
Case-specific			
Gender[a]	0.070*	0.015	0.085**
Marital status	0.004	0.023	– 0.026
Years spent in school	0.007	– 0.013	0.006
Membership to a group	0.041	– 0.061	0.021
Off-farm income	– 0.003	0.056	– 0.053
Number of agroforestry training sessions attended	– 0.098**	0.090	0.008
Total land owned (acres)	– 0.005	– 0.011	0.017**
Perceived value of the technology	0.029***	0.091***	0.043***
Ease of use of a technology	– 0.026	0.004	0.022
Compatibility with crops	– 0.019	– 0.002	0.021
Peer influence	0.027**	– 0.027	– 0.000
Perceived behavioral control	0.031**	0.034*	0.003

[a]Marginal effect as gender (binary variable) changes from 0 to 1. *, ** and *** indicate statistical significance level at 10%, 5% and 1% respectively

they can integrate several tree species to tap into a variety of anticipated benefits (Lamond et al. 2016; Vandreé et al. 2017).

Gender significantly increases the choice probability of boundary planting and woodlot technologies but not intercropping. A discrete change in gender from 0 to 1 (female to male) increases the choice probability of boundary planting and woodlot technology by 7.0 percentage points and 8.5 percentage points respectively, with the most prominent effect occurring in the woodlot. Previous studies have shown gender to significantly influence agroforestry choice decisions (Wambugu et al. 2011; Kiyingi et al. 2016). Men in the eastern highlands have better access to land than their women counterparts due to socio-cultural norms that perpetuate male inheritance of property (Bernard et al. 2020). The security of tenure to land commonly attained through succession makes men more likely than their female counterparts to choose the woodlot technology where associated benefits are long term. Also, men are more likely to select the woodlot technology associated with income-generating products like timber and poles (Mignouna et al. 2011; Kassie et al. 2013; Kiyingi et al. 2016). The idea of men dominating income-generating activities is supported by Anderson et al. (2016), who argue that men are more likely to engage in income-generating enterprises while women are more likely to be involved in those activities that provide food to the household. Men are also more likely than women to choose boundary planting technology, possibly because integrating trees along plot boundaries has evolved in parallel with a customary practice of securing land for which rights of use have been acquired (Dewees 1995). The trees in the boundary planting technology serve as robust physical markers that designate land boundaries. It emerged from FGDs that as default owners of the land, men tend to know better than women the actual boundaries of the land plots.

The number of agroforestry training sessions attended significantly decreases the choice probability of boundary planting option compared to other agroforestry technologies. A one-unit increase in the number of agroforestry training sessions attended decreases the choice probability for boundary planting by 9.8 percentage points. Before being trained, the boundary technology would appeal to smallholder farmers who fear that trees negatively impact crops if planted nearby (Mwangi and Kariuki 2015). Agroforestry trainings empower smallholder farmers with knowledge about tree-crop interactions and tree management options so that they more objectively evaluate their technological options (Anang et al. 2015; Nigussie et al. 2017). It is, therefore, possible that as smallholder farmers received more agroforestry training sessions, they were more likely to choose other seemingly more rewarding agroforestry technologies.

Total land owned significantly increases the choice probability of the woodlot as compared to other alternatives. A unit increase in the number of acres of land owned by the smallholder farmer increases the choice probability for the woodlot option by 1.7 percentage points. There is great importance attached to land size about the choice of the woodlot technology because it requires smallholder farmers to designate part of their land exclusively to tree growing. Other studies have highlighted the importance of land in influencing the choice decisions of smallholder farmers regarding new agricultural technologies (Kiyingi et al. 2016; Nigussie et al. 2017). The FGDs revealed that the priority for most smallholder farmers is to secure food for their households rather than take risks investing their time and labour in technologies where the anticipated benefits are in the long term. These results reinforce findings from previous studies highlighting that the overriding priority to most farmers is food security (Meijer et al. 2015). The woodlot technology does not directly contribute to food security. Therefore land availability is a motivation for smallholder farmers to experiment with the woodlot technology they are less familiar with (Kiyingi et al. 2016).

The perceived value of technology significantly increases the choice probability of all the agroforestry practices. A positive perception of the value of the agroforestry technology increases the choice probability of boundary planting, intercropping and woodlot by 2.9, 9.1 and 4.3 percentage points, respectively. The higher the perceived value of the technology, the more likely the smallholder farmer chooses it over other technologies. The most significant influence occurs in intercropping as compared to other technologies. Smallholder farmers tend to grow precious tree species in plots where they are easily monitored (Whitney et al. 2017). The intercropping technology ensures that trees planted can be monitored and managed alongside crops. Thus, highly valued tree species such as fruit trees that directly contribute to the food and income security of the household are often integrated into crop fields (Kalanzi and Nansereko 2015; Nyaga et al. 2015). On the other hand, while smallholder farmers focus more on food security, some try out technologies with higher anticipated economic value. This explains the increase in the choice probability of the woodlot technology where tree species such as *Eucalyptus* spp., *Grevillea* *robusta* and *Neolamarckia cadamba* that produce highly marketable wood products such as timber and poles, are integrated as observed in other studies (Nyaga et al. 2015; Nath et al. 2016).

Peer influence significantly increased the choice probability of the boundary planting technology by 2.7 percentage points but not intercropping nor woodlot technologies. Smallholder farmers using the boundary planting technology are more often influenced by their peers. The aspect of some smallholder farmers influencing their peers regarding technological choice decisions has been supported by many studies in agriculture (Zubair and Garforth 2006; McGinty et al. 2008; Meijer et al. 2015; Aziz and Afaq 2018; Zahid and Din 2019). The results are more varied in studies related to agroforestry. A study by Ofoegbu and Ifejika (2017), for example, reported that peer influence had the most significant effect on smallholder farmers' choice of sustainable forest use and management options in South Africa. A recent study by Buyinza et al. (2020) did not find peer influence as a significant factor in influencing smallholder farmers intention to integrate trees in their coffee plantations in the Mt. Elgon region of Uganda. In the context of this study, smallholder farmers seem to have been more familiar with the boundary planting technology. It was possibly more natural for them to use simple messages to influence their peers within the community (Kiptot et al. 2006).

On average, a unit increase in perceived behavioural control (farmer's positive perception of their ability) increases the choice probability for each of the boundary planting and intercropping technologies by 3.1 and 3.4 percentage points, respectively but not woodlot. Many smallholder farmers don't believe that they have enough land to designate a plot exclusively for woodlot establishment because their main priority is to secure food. During the FGDs, smallholder farmers were found to have more previous experience in planting or retaining trees along the boundary of their farms or in their crop fields. This made it easy for them to embrace boundary planting and intercropping technologies. It has been noted that smallholder farmers are risk-averse and tend to select technologies they are more familiar with (Kidane et al. 2019; Mukasa 2018). In the case of boundary planting and intercropping, our results support earlier findings that show that farmers' choice decisions of new agricultural technologies are influenced by the positive perception of their abilities to implement them (Md Husin and Ab Rahman 2016; Meijer et al. 2015; Van Hulst and Posthumus 2016; Denkyirah et al. 2017).

Conclusion

The study provides strong empirical insights into how smallholder farmers' socio-technological contexts explain their choice decisions among the predominant agroforestry technologies. Our results show that the most critical socio-technological factors which cut across the three agroforestry technologies were the number of tree species desired by the farmer and the perceived value of the technology. Other factors such as gender, number of agroforestry training sessions attended, total land owned, peer influence and perceived behavioural control were largely technology-specific. Gender, the number of agroforestry training sessions attended, peer influence and perceived behavioural control influenced smallholder farmers' choice of the boundary planting technology. Perceived behavioural control was the other socio-technological factor influencing smallholder farmers' decision of the intercropping technology. The study findings also show that efforts to scale-up the woodlot agroforestry technology in the eastern highlands of Uganda will be most successful if it focuses on male smallholder farmers holding a positive perception of the value of trees, with land size above average.

This study demonstrates the use of the decomposed theory of planned behaviour (DTPB) framework to explain the socio-technological drivers of smallholder farmers' choices of agroforestry technologies. This study showed how the various constructs of DTPB (Perceived value, ease of use, compatibility, peer influence, and perceived behavioural control) influence smallholder farmers' choice decisions of agroforestry technology. Our findings show that the construct of perceived value had the most significant influence on farmers choice of agroforestry technology. Perceived value, which is one of the three cognitive components of attitude, the other two being ease of use and compatibility, its significant influence justifies the decomposition of attitude, allowing more specific analysis of the constructs. Therefore, DTPB that decomposes attitude allows more specific conclusions to be drawn than the Theory of Planned Behaviour (TPB) which treats attitude as a unidimensional construct.

Our findings show a positive impact of peer influence on smallholder farmers' choice of boundary planting technology but not other technologies. The positive effect of peer influence is probably because smallholder farmers had more tacit and indigenous knowledge on boundary planting than other technologies that they relied on to influence their peers. Peer influence in technology adaptation and dissemination in agriculture has been a basis for developing farmer-led extension approaches, but this has not been tried out on long-term agroforestry. Agroforestry extension programmes could capitalise on peer influence to design farmer to farmer extension messages for promoting the boundary planting technology in the eastern highlands of Uganda.

The significant influence of perceived behavioural control on choice decisions of boundary planting and intercropping implies that when smallholder farmers believe in their abilities to implement a given technology, they are more likely to choose it. This means that planning of agroforestry extension interventions should also focus more on building the confidence of smallholder farmers to use the resources they have than providing external material support such as free tree seedlings when promoting the boundary planting and intercropping technologies.

This study provides robust empirical findings based on smallholder farmers in the eastern highlands of Uganda to underline the importance of incorporating socio-technological factors to promote agroforestry technologies. Other extrinsic factors affect smallholder farmers' decision choices but not considered in this study. For example, institutional factors could be incorporated into future studies. Results of this study can help inform similar agroforestry interventions in areas with similar contexts. To scale-up agroforestry technologies across agricultural landscapes, similar studies need to be replicated over larger areas.

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