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Received: 8 January 2024 | Accepted: 16 November 2024

DOI: 10.1002/pan3.10774

BRITISH ECOLOGICAL SOCIETY People and Nature

RESEARCH ARTICLE

Trees for Climate Change, Biodiversity and People

Understanding smallholder decision-making to increase farm tree diversity: Enablers and barriers for forest landscape restoration in Western Kenya

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Funding information
Bakala Foundation; Alliance of Bioversity International and CIAT

Handling Editor: Martin Dallimer

Abstract

1. Integrating diverse trees and shrubs (hereafter 'trees') in agricultural landscapes has emerged as a crucial nature-based solution to the triple challenge of biodiversity loss, climate change and food security. The potential benefits of on-farm trees for both people and nature, however, are often constrained by inadequate consideration of local socio-ecological factors and an overall lack of species diversity. A deeper understanding of what drives farmers' decision-making in diversifying farm trees is needed to ensure that scaling up tree-based restoration efforts in smallholder landscapes delivers the promised benefits locally and globally.
2. We conducted surveys with 620 smallholder farmers across Vihiga County in Western Kenya using an extended version of the Theory of Planned Behaviour to investigate potential drivers of smallholder intentions to grow more diverse woody plants on their farms. Data was analysed using Structural Equation Modelling (SEM).
3. We found that farmers were more likely to diversify on-farm trees if they had completed education beyond secondary school, derived all their income from their farms, were household heads and were among the wealthiest 20% of farmers.
4. Our results revealed that farmers' decisions about increasing tree diversity were also influenced by socio-psychological factors, namely their past experiences, the perceived behaviour and opinions of other farmers, their confidence in their ability to increase tree diversity, and their attitudes toward the expected outcomes of growing a wider range of tree species. Key barriers preventing farmers from

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diversifying were concerns about attracting harmful wildlife, decreasing soil fertility, small farm sizes, lack of time and knowledge, and certain cultural beliefs about planting trees.

5. *Synthesis and applications*. Understanding the factors influencing farmers' intentions to increase tree diversity on their farms has substantial implications for the success of nature-based solutions in Western Kenya and other densely populated smallholder landscapes. Addressing the identified barriers and enablers is crucial to design targeted interventions to promote sustainable tree diversification practices among smallholders to bolster local livelihoods and food security while contributing to biodiversity conservation and climate change mitigation.

KEYWORDS
agroforestry, ecosystem services, farmer behaviour, forest landscape restoration, nature-based solutions, smallholder livelihoods, structural equation modelling, theory of planned behaviour

1 | INTRODUCTION

Agriculture is the largest single driver of environmental degradation and biodiversity loss whilst simultaneously suffering drastically from its consequences, threatening multiple ecosystem services upon which society relies (Rockström et al., 2020). Therefore, nature-based solutions are needed to equitably support food production and diverse livelihoods while ensuring that agriculture is a net positive contributor to biodiversity and nature (Cohen-Shacham et al., 2016). Halting the expansion of agriculture into intact ecosystems is critical to stop biodiversity loss and mitigate climate change. At the same time, agricultural diversification strategies are needed to create more resilient production landscapes (DeClerck et al., 2023). These strategies can help farms adapt to and recover from climate and environmental changes while maintaining productivity and essential ecosystem services.

Integrating a diverse mix of shrubs and trees into agricultural landscapes has the potential to contribute toward tackling the triple challenge of biodiversity loss, climate change and food insecurity (Ickowitz et al., 2022; Kuyah et al., 2019). Agroforestry, defined here broadly as the integration of shrubs and trees into farming landscapes, can contribute to the restoration of multiple ecosystem functions and services, ranging from enhanced carbon storage and sequestration (Ma et al., 2020), to increased soil functions (Li et al., 2022; Muchane et al., 2020), pollination (Centeno-Alvarado et al., 2023) and improved food and nutrition security (Ickowitz et al., 2022; Jansen et al., 2020). Moreover, growing trees on farms can also help reduce the pressure on natural forests and mitigate forest degradation, thus contributing to the conservation of biodiversity (DeFries et al., 2022).

Agroforestry practices are particularly relevant and proliferating in densely populated agricultural landscapes in tropical developing countries, where demand for natural resources and the rate of biodiversity loss continue to increase (FAO et al., 2019). In Sub-Saharan Africa, where most food is produced on farms smaller than 1 hectare (Giller et al., 2021), over 70% of the countries have committed to using agroforestry for climate change mitigation under their Nationally Determined Contributions as part of the United Nations Framework Convention on Climate Change (UNFCCC) (Rosenstock et al., 2019). For example, the Kenyan government has launched a campaign to plant 15 billion trees by 2032 as part of the 30 by 30 initiative (Kenyan Government, 2023).

The benefits of tree planting, however, are often constrained by lack of consideration for local socio-ecological aspects in species selection and overall low species diversity (Di Sacco et al., 2021; Martin et al., 2021). Considerable gaps in native tree seed supply systems further hinder access to high-quality seeds and seedlings (Giacomini et al., 2023). A review of pantropical tree planting organisations found that many organisations do not report which tree species they planted and of those that do, over 50% reported planting five or fewer species, often prioritising commercially useful and non-native species which may limit the future biodiversity (Martin et al., 2021). Yet, agroforestry systems with higher (functional) plant diversity have been found to support higher biodiversity and provide more supporting ecosystem services (Santos et al., 2019; Tschora & Cherubini, 2020). Efforts to increase tree cover in agricultural landscapes thus need to shift from solely increasing tree numbers to meeting farmers' needs by growing a diversity of native trees (Derero et al., 2021). Previous research in Sub-Saharan Africa found that farmers are interested in higher species diversity for on-farm trees (Derero et al., 2021; Dumont et al., 2019), but research exploring the barriers and enablers that smallholder farmers are facing in their decision-making is lacking.

Here, we adopted the Theory of Planned Behaviour (TPB), a theoretical framework widely used to investigate farmers' decision-making (Rose et al., 2018; Sok et al., 2021), to explore factors that influence smallholder farmers' decisions in diversifying trees and shrubs (hereafter 'trees') on their farms. The TPB has been effectively

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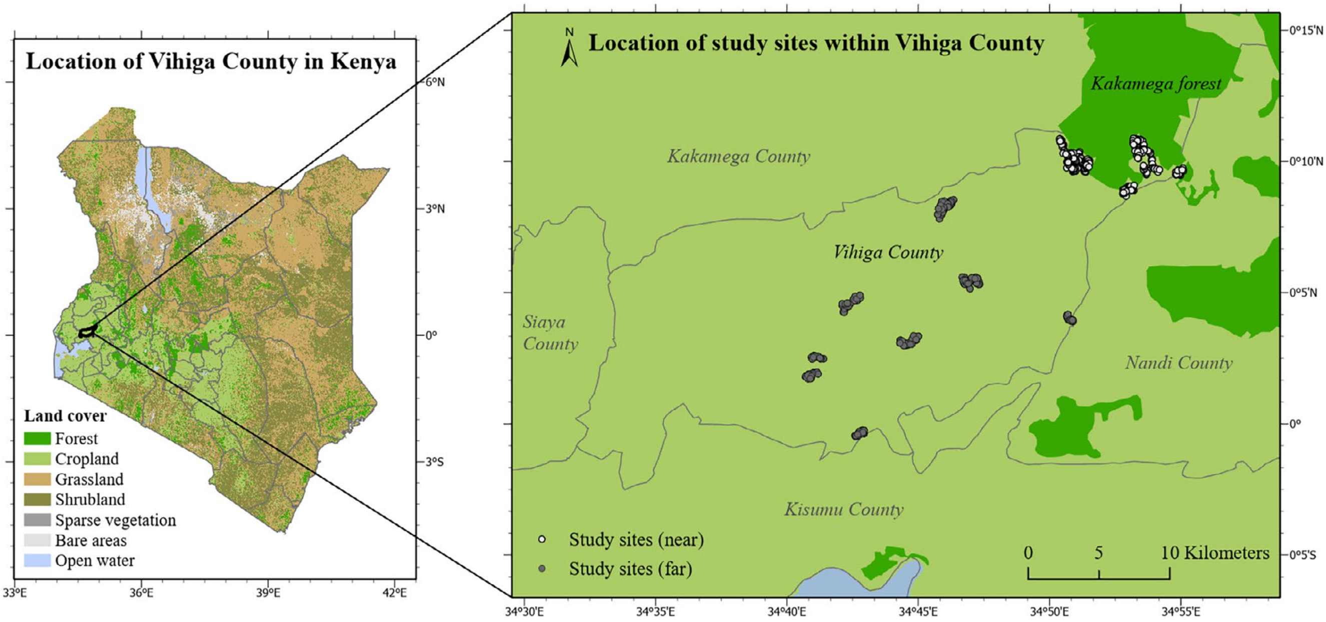

FIGURE 1 Map of the study area showing the location of Vihiga in Kenya and the geographical distribution of the study sites within the County. Six hundred and twenty-five in-person surveys were completed, of which 305 surveys were conducted in farms 'far' from Kakamega forest (filled circles) and 320 surveys in farms 'near' the forest (empty circles). Land cover types were classified using Sentinel-2 global land cover data from 2016 (Regional Centre for Mapping of Resource for Development, 2016).

used to explore smallholder farmers' intentions to plant trees in various contexts, such as Malawi (Meijer et al., 2015), Uganda (Kalanzi et al., 2021) and Pakistan (Ahmad et al., 2023). The Theory examines individuals' intentions based on an evaluation of three primary factors: (1) their attitude toward the desired behaviour, (2) the influence of others regarding this behaviour and (3) their self-assessed ability to carry it out (Ajzen, 1991, 2020) (Figure 2). These factors are formally summarised as attitudes, social norms and perceived behavioural control. The weighted contribution of each factor in the decision-making process varies on an individual basis and is shaped by (i) individual expectations and evaluations of likely outcomes, (ii) the influence of social pressure and (iii) the significance of barriers to carrying out the behaviour. These underlying beliefs are herein referred to as behavioural beliefs, normative beliefs and control beliefs. Evaluating these underpinning factors in individuals' decision-making offers valuable insights into the specific barriers and enablers that shape behavioural intentions, ultimately leading to targeted recommendations for conservation practice.

This study aimed to investigate factors that influence smallholders' intentions to increase the diversity of trees on their farms. We selected this specific farm practice due to its potential benefits for multiple ecosystem services, including pollination (Centeno-Alvarado et al., 2023), improved food and nutrition security (Ickowitz et al., 2022; Jansen et al., 2020) and enhanced carbon storage and sequestration (Ma et al., 2020). We conducted surveys with 620 smallholder farmers in Vihiga, Western Kenya, using an extended version of the TPB. The objectives of this study were to: (1) assess the potential influence of socio-demographic and farm characteristics on farmers' intention to diversify the trees and shrubs on their farms, (2) explore the socio-psychological factors that influence farmers' intentions and (3) investigate the underlying beliefs, encompassing both barriers and enablers, which shape these socio-psychological factors. By addressing these objectives, we can inform targeted interventions and policies that empower smallholder farmers to grow a more diverse range of trees and consequentially support the scaling up of tree-based forest landscape restoration.

2 | METHODS

2.1 | Study area

This study was conducted in Vihiga County, located in the upper midland agro-ecological zone of Western Kenya (Figure 1) and characterised by its high population density (1099 inhabitants/km^2) (MoALFC, 2021). Vihiga encompasses a portion of the Kakamega Forest, locally referred to as Kibiri Forest, the only remaining Guineo-Congolian rainforest in Kenya which supports rich biodiversity and provides ecosystem services estimated to be worth more than US$ 7.4 million per year (Mutoko et al., 2015). Over 75% of the county's land area consists of smallholder agriculture, where farmers grow crops such as maize and beans on an average household land size of 0.4 ha (1 acre) (The County Government of Vihiga, 2018). Smallholder agriculture is mostly rainfed and low input, providing the majority of employment opportunities. Despite the importance of crop production to Vihiga's economy, approximately 73% of households suffer from limited or uncertain access to adequate food and about 39% of the

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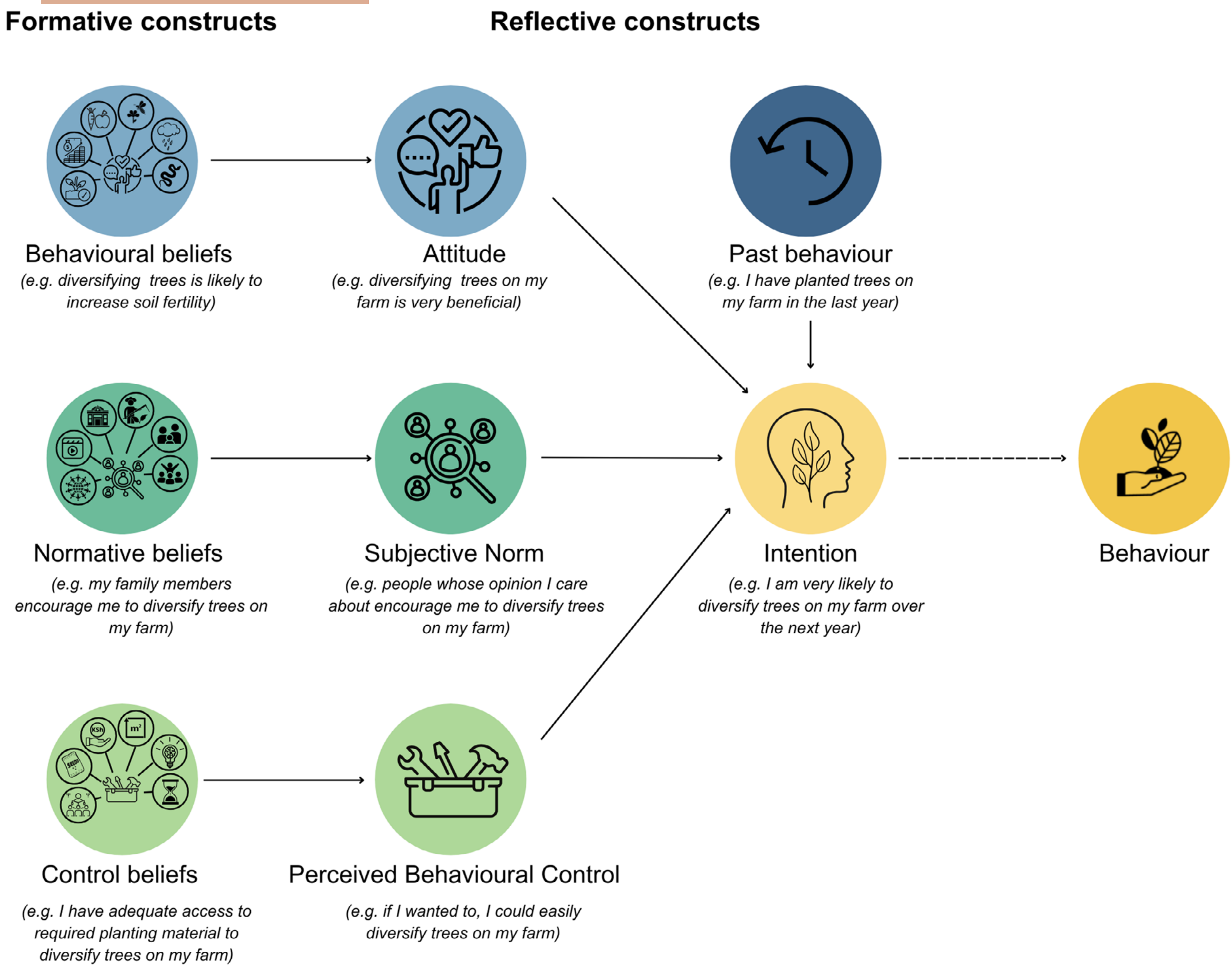

FIGURE 2 Extended version of the Theory of Planned Behaviour Model, developed for this study and adopted from Ajzen (1991). The formative beliefs (behavioural, normative and control beliefs) are on the left, indirectly influencing farmers' intention through the reflective constructs (attitude, subjective norm, perceived behavioural control and the additional predictor variable past behaviour). Example statements from the survey questionnaire are included for all constructs to illustrate the application of the framework in this study.

population live below the poverty line (less than USD 1.90 daily) (MoALFC, 2021; The County Government of Vihiga, 2018). Over recent decades, agricultural land has expanded at the cost of forest and other natural habitats, while population growth at an estimated annual rate of 3.7% between 1979 and 2009 has caused land degradation and declined soil fertility, and overall per capita food crop production has dropped by 28% over the same period (Mutoko et al., 2014).

2.2 | Study design and measures

In this study, we used a sequential mixed-methods design, wherein an initial qualitative phase was followed by a quantitative phase (Creswell & Creswell, 2017). This approach allowed us to use insights from the qualitative phase to shape the quantitative survey, ensuring its relevance to the local context and practices of smallholder farmers in Vihiga County. First, four focus group discussions (FGDs) were conducted with 48 smallholder farmers in Vihiga to explore farmers' adoption of and perspectives on diverse pollinator-friendly farming practices, such as using only organic pesticides, planting native trees and diversifying crops. Insights from the FGDs revealed that farmers had a limited understanding of the role of insect pollinators and did not consider pollinators much in their decision-making (see a summary of key findings of the FGDs in Appendix 1). The FGDs were then used to select one pollinator-friendly farming practice that was relevant to the local context and had relatively low adoption rates among farmers, offering an opportunity for further investigation and potential recommendations for its promotion. The insights gained from the FGDs thus guided the development of the quantitative survey questionnaire, resulting in focusing the survey on increasing tree diversity on the farms as a farming practice with multiple benefits, including supporting wild pollinators. A subset of the questions

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in the survey continue to address the relationship between tree-planting decisions and supporting pollinators. To refine the survey and improve question structure, wording and clarity, a pilot study with 107 farmers in different non-study areas was then carried out. Further details on the FGDs, pilot study and the full questionnaire are available in Appendices 1–4.

The final in-person survey questionnaire contained 31 questions, combining open-ended and closed questions to investigate the factors that may influence farmers' intentions to diversify the trees and shrubs on their farms (Figure 2). We used and adopted the TPB framework to develop the questionnaire design (Ajzen, 1991; Sok et al., 2021). While the TPB posits that attitude, subjective norm and perceived behavioural control are the key predictors of intention, past behaviour and experience play an important role in farmers decision-making (Rose et al., 2018). It is also one of the most frequently suggested additional constructs to be added to the TPB (Sommer, 2011) and many studies using the TPB to explore farmer behaviour have added it to the framework (Sok et al., 2021). We thus extended the TPB by adding past behaviour to explore its potential influence on farmers' intentions.

The TPB further recognises that background variables such as gender, age and education may influence behaviour in addition to the Theory's key constructs (Fishbein & Ajzen, 2010). Contemporary studies on farmer behaviour highlight the importance of particular socio-demographic and farm characteristics (Rose et al., 2018; Sok et al., 2021). To investigate how these factors affect farmers' intentions, we included questions about farmers' socio-demographic attributes (age, sex, education, household size, household head, relative wealth, membership in farmers' groups, land tenure and proportional contribution of farm income to total income) and farm characteristics (farm size and distance to the forest). A detailed overview of the reasoning for including each of these variables and our hypotheses regarding their effects on farmers' intentions is provided in Table S1. All references exclusively cited in the Supporting Information are listed under 'Additional references'.

All socio-psychological components used to understand and analyse farmers' behaviour (so-called 'constructs' in the TPB) were defined and assessed to conform to the principle of compatibility (i.e. all constructs correspond to the same behaviour). We also applied the TACT principle, by which the behaviour is defined according to target, action, context and time (TACT) (Sok et al., 2021). In this study, we examined smallholders' intentions to diversify (action) the trees and shrubs (target) on their farms (context) over the next 12 months (time). Farmers' attitude toward the behaviour, subjective norm, perceived behavioural control, past behaviour and intention were assessed using reflective indicators, which are sets of items designed to provide relatively direct measures of these constructs (Ajzen, 2020). A total of nine statements were used to measure the reflective items (Table 1), and we further included 19 items assessing behavioural, normative and control beliefs (Table 2). Following the expectancy-value model proposed by Ajzen (2020), we used two items to assess each belief, namely the strength of beliefs and their corresponding evaluations (Table 2; more detailed explanation in Appendix 6). We used 5-point Likert-type scales for all original TPB constructs, with one point being the most negative answer and five the most positive one.

TABLE 1 Reflective ('direct') measures: Statements and scales used to measure intention (INT), attitude (ATT), subjective norm (SJN), perceived behavioural control (PBC) and past tree planting behaviour (PTP).

Variable statements		Scale (1–5)
INT	How likely are you to diversify the trees and shrubs on your farm over the next year?	Very unlikely to very likely
ATT_1	How do you feel about diversifying the trees and shrubs on your farm?	Not at all contented to very contented
ATT_2	How do you feel about diversifying the trees and shrubs on your farm?	Not at all beneficial to very beneficial
SJN_1	What do people whose opinion you care about think about you diversifying the trees and shrubs on your farm	Definitely should not to definitely should
SJN_2	How likely are these people to diversify the trees and shrubs on their own farms?	Very unlikely to very likely
PBC_1	To what extent do you feel that—if you wanted to—diversifying the trees and shrubs on your farm within the next year is within your control?	Completely out of my control to completely within my control
PBC_2	If you wanted to, how easily could you diversify the trees and shrubs on your farm in the next year?	Very difficult to very easily
PTP_1	In the last 12 months, have you planted any shrubs and/or trees on your farm? (Paraphrased for clarity; Appendix 4)	Yes/no (binary)
PTP_2	In the last 12 months, have you supported insect pollinators by planting flowering plants on your farm? (Paraphrased for clarity; Appendix 4)	Yes/no (binary)

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TABLE 2 Formative ('indirect') measures: Possible outcomes (*i*), important referents (*j*) and control factors (*k*) included in the final survey questionnaire.

Possible outcomes (*i*)	Important referents (*j*)	Control factors (*k*)
• Increased soil fertility • More pollinators • Increased crop yield • Increased livelihood benefits (e.g. food, firewood, medicine and income) • Increased visitation of harmful animals (e.g. pests, dangerous bees, chameleons and snakes)[a] • Contribution toward mitigating climate change (e.g. rainfall, soil stability, CO_2 sequestration)	• Family members • Community elders and leaders • Other farmers • NGOs • Farmer groups • Ministry of agriculture • Media programs	• Knowledge • Farm size • Access to required planting material • Financial resources • Time • Cultural beliefs (e.g. gender roles and certain trees being a bad omen)

Note: These variables were identified based on insights from the focus group discussions (methods detailed in Appendices 1 and 2).

[a]While all other possible outcomes of tree diversification are positive, the increased visitation of harmful animals is a potentially negative outcome and thus results were interpreted accordingly.

2.3 | Data collection

Data collection was conducted between January and March 2023 in 20 farming communities in Vihiga. We sampled a similar number of farms near (<1 km) and far (>5 km) from Kakamega forest as a farm characteristic to explore if the distance to the forest influenced farmers' intentions to diversify on-farm trees. Surveys took between 25 and 40 min to complete, and data were collected on tablets using an offline version of the Open Data Kit (ODK) collection software. These in-person questionnaires were administered in the local dialect of Kiswahili by four research assistants who received comprehensive interview and data collection training before data collection. Further information on the data collection and sampling can be found in Appendix 7.

Before administering the questionnaires, the interviewers provided a brief description of the main aims of the study, emphasised that participation was completely voluntary and anonymous, and reassured participants that they could stop the interview at any time if they wished. Each participant had the opportunity to ask questions about the project and signed the project consent sheet before participating in the survey. The information sheet and consent form for participants can be found in Appendices 4 (English) and 5 (Kiswahili), alongside the survey questionnaires. Ethical approval for this study was obtained from the Kenyan Amref Health Africa Ethics and Scientific Research Committee (approval number ESRCP1363/2023) and the University of Exeter's Research Ethics Committee (Ethics Application ID: 511170).

2.4 | Data analysis

To explore the effects of socio-demographic and farm variables on farmers' intention to diversify, we applied ordinal logistic regressions (OLR), a widely used method for ordinal response variables (Harrell, 2015). While the TPB postulates that background factors influence intentions only indirectly, we regressed factors directly on intentions like most studies investigating farmer behaviour using the TPB (Sok et al., 2021) to ensure statistical power. Furthermore, this approach should enhance the accessibility and clarity of the interpretation of our study findings, particularly given the already complex nature of our extended TPB model. Prior to data analysis, we removed variables with >5% missing values and used predictive mean matching to impute missing data for variables with <5% missing values. We confirmed that results remained qualitatively similar when comparing the imputed data with a complete case analysis excluding missing values. As the results were qualitatively similar but quantitatively more robust using data imputation, we thus focus only on findings from the imputed data.

We constructed a global model that included all potential predictors of farmers' intention to diversify (namely the socio-demographic characteristics; age, sex, education, household size, household head, relative wealth, land tenure, proportional contribution of farm income to total income and membership in farmers' group, as well as the farm characteristics; farm size and distance to the forest). Akaike information criterion (AIC) was used to optimise model selection, considering all possible model combinations of log-likelihood whilst factoring the number of parameters (Wagenmakers & Farrell, 2004). Final models were calculated as an average across models with AIC<4 (Table S7) (Anderson & Burnham, 2002), using the MuMIn package v.1.42.1 (Barton, 2018). The relative importance of predictor variables (RVI) is represented as the sum of Akaike weights for variables present in the final averaged models (Table S8). We used 95% confidence interval to retain variables in best performing models supported by lower AIC values (Arnold, 2010). Statistical analysis was conducted using R version 4.2.2 (R Core Team, 2022). To determine the relative wealth of our study population in comparison to the national population in Kenya, we applied the national quintile syntax provided by the Kenya Equity Tool using the STATA statistical software (Kenya EquityTool, 2022).

We used Partial Least Squares Structural Equation Modelling (PLS-SEM; Sok et al., 2021) to investigate relationships between variables of the TPB model. PLS is a variance-based, non-parametric SEM method and can handle complex models including reflective

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and formative measurement models, as well as single-item constructs (Hair et al., 2021). The causal-predictive nature of PLS-SEM also makes it particularly useful for research aiming to derive recommendations for practice (Hair et al., 2021). Prior to the statistical analysis, all responses 'I don't know' and 'I prefer not to say' were classified as missing values. We removed variables and respondents with >15% missing values, as high rates of missing data may have severe impacts on the interpretation and the accuracy of model results (Lopucki et al., 2022). This led to the exclusion of five respondents and three variables, namely the influence and importance of 'farmers groups' and the 'Ministry of Agriculture' in shaping farmers' subjective norms, and the likelihood of tree diversification on increasing 'pollinators' as well as the importance of increasing 'pollinators' on farms (variables excluded: beliefs about farmer groups, the Ministry of Agriculture and pollinators) from the PLS-SEM analysis. For the remaining missing data, we used mean replacement to estimate replacement values, which is deemed a suitable technique when degree of missingness is small (<5% values missing per indicator) and the sample size is large (Hair et al., 2021).

As PLS-SEM does not provide a global goodness-of-fit parameter (Hair et al., 2021), we evaluated the measurement and structural models based on a list of recommended criteria. The reflective measurement model was assessed on the grounds of indicator reliability, internal consistency reliability, convergent validity and discriminant validity, and the formative measurement model based on indicator collinearity and the significance and relevance of indicator weights (Hair et al., 2021). We evaluated the structural model based on collinearity among sets of predictor constructs, significance and relevance of path coefficients and the explanatory power of the model. Additional information on the PLS-SEM procedure and model evaluation is provided in Appendix 8. Statistical analyses were conducted using the *SEMinR* package in R version 4.2.2 (R Core Team, 2022; Ray et al., 2021) and the SmartPLS4 software application (Ringle et al., 2022).

Inductive thematic coding was used to analyse the responses to open-ended questions and gain deeper understanding of various aspects related to on-farm tree diversification because it allows themes and patterns to emerge organically from the data without preconceived expectations or predefined coding categories (Thomas, 2003). After an initial familiarisation with the open-ended responses, the raw data was thematically coded in an iterative process (Nowell et al., 2017). The results obtained from the qualitative analysis are presented alongside the results from the quantitative analysis to provide a more in-depth understanding of the factors that affect farmers' intention to grow a more diverse mix of trees on their farms.

3 | RESULTS

3.1 | Study population

Of a total of 625 participants, we considered 620 valid responses for analysis. The majority of participants cultivated their own land (78%), and most farmed land that was smaller than 1 acre (73%). Integration of trees on the farms is widespread in Vihiga, and we found that smallholders manage on-farms trees for a multitude of purposes, including firewood (95%), food (82%), shade (80%) and timber (66%) (Table S10). Reliance upon resources from on-farm trees was further highlighted by the results of the Kenya Equity Tool questions about farmers' relative wealth, indicating that a considerable proportion of respondents (94%) relied on wood as their primary fuel source for cooking. Approximately half of the participants derived their income exclusively from selling what they produce on their farms (53%), while the other half of the study population had additional income from alternative sources. The respondents' distribution of relative wealth was largely representative of Kenya's wider population (DNMP and KNBS, 2021; Kenya EquityTool, 2022), with 13% of respondents in quintile 1 (the poorest), 17% in quintile 2, 38% in quintile 3, 25% in quintile 4 and 7% in quintile 5 (the wealthiest). A more detailed overview of the study population information can be found in Table S9.

3.2 | Socio-demographic and farm characteristics that influence farmers' intentions to diversify

The majority of respondents reported high levels of intention to diversify trees on their farms over the next 12 months (83% *likely* and *very likely*) and showed positive attitudes, subjective norms, and perceived behavioural control toward diversifying (Figure S3). When investigating the effects of socio-demographic and farm characteristics on farmers' intentions to diversify, the results from the OLR suggest that household head status, relative wealth and income diversity were the most important variables for understanding variation in farmers' intentions to diversify (Figure 3; Table S8). Post-secondary school education, that is, completing a diploma or university degree, also played an informative role in influencing farmers' intentions, but contribution to the overall model was very low (RVI = 0.04). Farm size was removed from the analysis because it had >5% missing values. 95% CIs for distance to the forest, household size, sex, land tenure, membership of farmers group, and age overlapped zero, which decreased our confidence in the direction of these effects. Farmers' higher intentions to diversify were more likely when respondents had higher relative wealth, education, household head status, or did not have other income apart from farming.

3.3 | Socio-psychological factors that influence farmers' intentions to diversify

Results from the PLS-SEM revealed that attitude, subjective norm, perceived behavioural control and past behaviour all had positive and statistically relevant effects on intention (Table 3; Figure 4). In the following paragraphs, we present findings on each of these constructs, including the underlying beliefs which shape the socio-psychological factors, and share insights from the open-ended questions that provide relevant context for the results from the quantitative analysis.

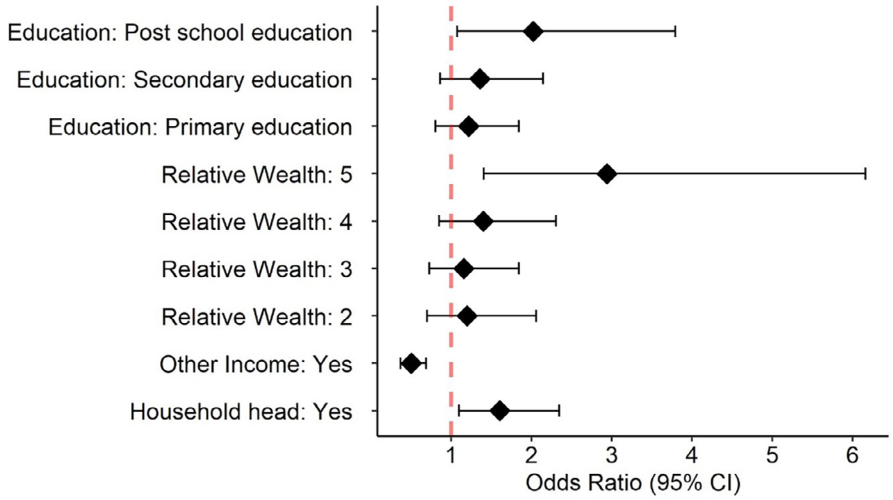

FIGURE 3 Odds ratios (with 95% confidence intervals) of increase in survey respondents' intention to diversify on-farm trees as a function of the socio-demographic characteristics. Each level shown is compared with reference. Reference levels: Education = No formal education, Relative wealth = 1, Other income = No, Household head = No. Red line represents odd ratio = 1. Relative variable importance (RVI) values are Education = 4%, Relative wealth = 42%, Other income = 63%, Household head = 60%.

TABLE 3 Path coefficients of the direct effects of attitude (ATT), subjective norm (SJN) and perceived behavioural control (PBC) on intention (INT) and the formative beliefs on ATT, SJN and PBC. The formative beliefs refer to the items described in Table 2. A visual presentation of the findings of the SEM can be found in Figure 4. Significance of the coefficients is represented as follows: *p*-value (**p* ≤ 0.05; ***p* ≤ 0.01; ****p* ≤ 0.001).

Variables	Beta coefficient	SD	*t* statistics	*p*-values
ATT → INT	0.107	0.042	2.540	0.011*
SJN → INT	0.211	0.045	4.679	<0.001***
PBC → INT	0.143	0.044	3.249	0.001***
Past behaviour → INT	0.352	0.078	4.501	<0.001***
Behavioural beliefs				
Mitigating climate change → ATT	−0.063	0.049	1.299	0.194
Visitation of harmful animals → ATT	0.300	0.050	5.981	<0.001***
Increased livelihood benefits → ATT	−0.120	0.080	1.496	0.135
Increased soil fertility → ATT	−0.121	0.053	2.303	0.021*
Increased crop yield → ATT	0.064	0.071	0.905	0.366
Normative beliefs				
Family members → SJN	0.059	0.047	1.254	0.210
Community elders and leaders → SJN	0.084	0.047	1.804	0.071
Media programs → SJN	0.026	0.044	0.598	0.550
Other farmers → SJN	0.176	0.052	3.364	0.001***
NGOs → SJN	0.032	0.048	0.674	0.500
Control beliefs				
Cultural beliefs → PBC	0.090	0.045	2.015	0.044*
Farm size → PBC	0.147	0.034	4.339	<0.001***
Time → PBC	0.132	0.057	2.332	0.020*
Financial resources → PBC	0.058	0.038	1.513	0.130
Knowledge → PBC	0.284	0.045	6.300	<0.001***
Access to required planting material → PBC	0.005	0.050	0.102	0.919

3.3.1 | Past behaviour

Farmers' past tree planting behaviour had a positive effect on their intention to grow a more diverse mix of trees over the next 12 months. Compared to the parsimonious TPB model ($R^2 = 0.107$) (Figure S2), the inclusion of past behaviour increased the variance explained by the model ($R^2 = 0.134$). Most farmers self-reported having planted trees on their farms over the last 12 months (75%), and their main purposes for on-farm trees included firewood (95%), food (82%), shade (80%) and timber (66%). Although a majority of farmers (64%) reported having planted (not exclusively) non-native species, such as eucalyptus, most respondents (80%) also mentioned

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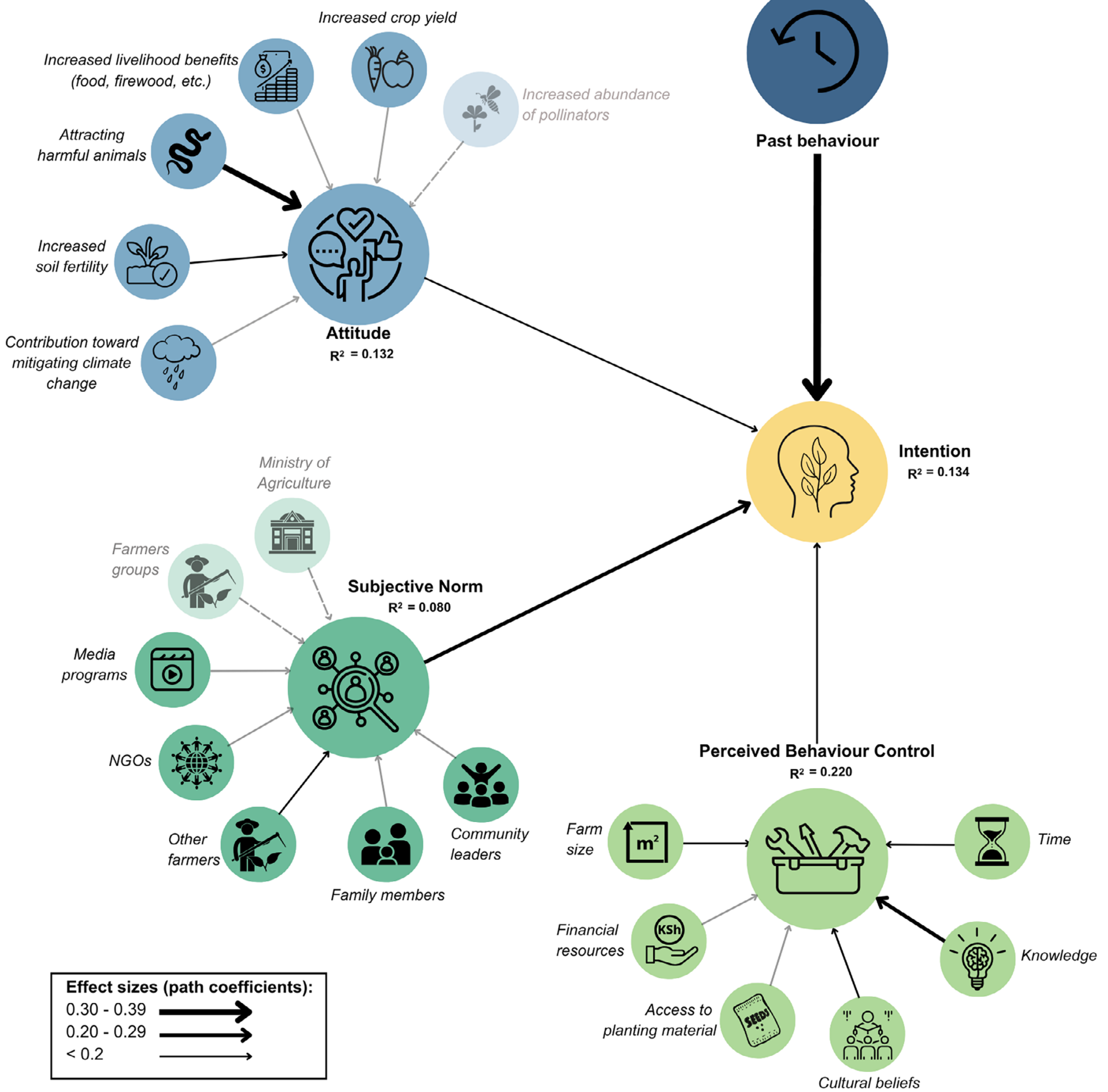

FIGURE 4 Path diagram presenting the results of the PLS-SEM (Table 3); illustrating the effects of attitude, subjective norm, perceived behavioural control and past behaviour on farmers' intention to diversify trees on their farms over the next 12 months, and the effects of the underlying beliefs on attitude, subjective norm and perceived behavioural control. Reflective constructs are represented by large circles, and formative constructs are represented by small circles. Connections are illustrated in black for statistically significant results and faded for non-significant results. Width of arrows between constructs reflect the relative effect sizes (path coefficient). The determination coefficients (R^2) refer to variance explained in each endogenous reflective construct. Constructs that were removed due to high proportions of missing values are represented with a faded symbol and dashed arrow lines. See Figure S1 for the original PLS-SEM path diagram.

being conscious of the negative environmental impacts of eucalyptus trees. Among the most commonly cited consequences were the negative effects on water and nutrient availability in the soil and the competition for these resources against other crops.

While a total of 47% of the farmers reported that they had previously planted native tree species, it is worth noting that the distinction between non-native and native was not always clear. When asked which native trees they had planted, the most frequently listed trees were avocado, mango, guava, croton (*Croton macrostachyus*), shikhuma (*Zanthoxylum gilleti*) and lusiola (*Markhemia platycalyx*). The list of native trees incorrectly included non-native trees such as avocado, mango, guava but also eucalyptus, cypress

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and grevillea, indicating that the results with regard to native versus non-native species must be interpreted cautiously.

3.3.2 | Subjective norms and the role of influential others

Farmers perceived substantial social pressure and influence from important others regarding tree diversification (Table 3). Most farmers believed that influential others were likely to diversify the trees on their own farms (88%) and encourage others to do the same (80%) (Figure S5). In particular, the influence of other farmers had a positive effect on respondents' perceptions of social expectations about tree diversification (Table 3). Other people and information sources, namely family members, community elders and leaders, media programs and NGOs, had a negligible effect on farmers' subjective norms.

3.3.3 | Perceived behavioural control and control beliefs

Farmers' perceived control over diversifying the trees on their farms was an important factor influencing their intentions (Table 3). In general, respondents felt that diversifying woody habitat on their farms was within their control (92%) and easily achievable (92%). However, farmers reported several constraints regarding their abilities to grow a more diverse mix of trees, including small farm size and space constraints (35.4% of all respondents), and a lack of access to resources, such as suitable planting materials (29.5%). Other challenges were climate and weather, particularly lack of rains and prolonged dry seasons (16.6%), theft (10.9%), pests and diseases (8%), negative consequences of trees, such as attracting harmful wildlife and causing accidents (4%), social challenges including disputes with neighbours and cultural norms that make it culturally unacceptable for women to plant trees (3%).

When exploring the effects of the control beliefs on farmers' perceived behavioural control, knowledge had a positive effect on respondents' perceived behavioural control. Although not having access to the required planting material and lacking sufficient financial resources to diversify were frequently mentioned challenges (Figure S6), these beliefs had little impact on farmers' perceived behavioural control.

3.3.4 | Attitudes and farmers' evaluation of tree diversification outcomes

Farmers' attitude affected their intentions (Table 3), where farmers with more positive attitudes toward tree diversification were more likely to express positive intentions to grow a wider range of woody plants on their farms in the future. Overall, farmers perceived tree diversification as important and beneficial, and approximately half of the respondents reported feeling contented with the current level of diversity (Figure S3). More specifically, farmers perceived tree diversification as beneficial for mitigating climate change, increasing livelihood benefits and pollinator visitation (Figure S4). Among the behavioural beliefs shaping farmers attitude, however, only two specific beliefs were identified as relevant: the beliefs regarding increasing soil fertility and increasing visitation of harmful wildlife such as chameleons, snakes and bees (Table 3). This indicates that farmers saw potentially negative effects of tree diversification on soil fertility and attracting harmful animals such as insects, pests, chameleons, snakes and monkeys. Farmers' beliefs about the effects of diversification on and the importance of mitigating climate change, improving crop yield, and providing livelihood benefits did not have a statistically important effect on their attitude toward diversification.

As a considerable proportion of respondents were unsure or reluctant to assess the impact of tree diversification on pollinators (>15% responses 'I don't know' or 'Prefer not to say'), we excluded this variable from the SEM analysis. When qualitatively analysing farmers' responses to other survey questions about pollinators, however, we found that in general, wild pollinators seemed to be perceived as important for farmers' crops by the majority of the respondents (63%), and roughly a third of all famers (34%) indicated that they had actively supported pollinators on their farm over the last 12 months, for example by planting flowering plants or bee keeping. Yet, these responses need to be interpreted cautiously, as our survey also revealed a lack of knowledge among farmers regarding the function of pollinators for specific crops. For example, among those who perceived wild pollinators as important for their crops, the majority mentioned maize (77%), beans (63%), banana (31%), mango (25%) and avocado (21%) as the most dependent crops, while scientific evidence clearly shows that maize and banana do not rely on insect pollinators.

4 | DISCUSSION

Increasing the diversity of trees in productive landscapes can contribute to the restoration of multiple ecosystem functions and services (Centeno-Alvarado et al., 2023). To ensure that agroforestry practices deliver long-term benefits for both people and nature, it is essential to understand farmers' decision-making processes. This is particularly relevant and timely in Kenya, where the government has initiated an ambitious campaign to plant 15 billion trees by 2032, encouraging all citizens to plant at least 30 trees annually (Kenyan Government, 2023).

Here, we have identified the key factors that influence farmers' decisions to actively contribute toward increasing biodiversity by growing a greater diversity of trees on their land. Smallholders' intentions to increase on-farm tree cover and diversity were affected by their past decisions, the influential opinions and behaviours of other farmers, the perceived control over the behaviour, and attitudes toward diversification. Of the socio-demographic characteristics, relative wealth, education, household income diversity, and the

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household head status of the respondent impacted their intentions. These findings may potentially be applicable to sustainable agricultural practices and biodiversity conservation beyond Vihiga County, especially in other densely populated and degraded landscapes across much of Sub-Saharan Africa.

Our study used a sequential mixed-methods approach, where an initial qualitative phase in the form of FGDs was used to scope the subsequent quantitative survey with 620 smallholder farmers. The FGDs were broadly framed around pollinator-friendly farming practices such as planting native trees, crop diversification, and using only organic pesticides, however, insights from the discussions revealed that farmers had a limited understanding of the role of insect pollinators and did not consider pollinators much in their decision-making. We therefore narrowed the focus of the survey questionnaire to the diversification of on-farm trees. While pollinators might not play a key factor in farmers' decision-making process in our study area, increasing the diversity of trees in productive landscapes can contribute to the restoration of multiple ecosystem functions and services, including pollination (Centeno-Alvarado et al., 2023). This sequential approach suggests that grounding quantitative surveys in preliminary qualitative insights can help align study objectives with the local context, potentially making findings more relevant to the local community.

Below, we discuss a range of practical recommendations for supporting smallholder farmers in diversifying trees and agroforestry systems that could contribute to multiple sustainable development goals (SDGs), including zero hunger, climate action, and improving life on land.

4.1 | Past experiences and other farmers influence tree diversification intentions

Our findings highlight that farmers who have planted different trees on their farms in the past are more likely to continue to do so in the future. Equally, the opinions and behaviour of other farmers had an important influence on smallholder farmers' behaviour. These results suggest that showcasing successful examples of tree diversification among farmers who have a history of positive past experiences with tree diversification could serve as powerful motivators for others, leading to a wider adoption of tree diversification practices. This aligns with the concept of social learning, where farmers have been found to observe and replicate behaviours that have led to positive outcomes within their community (Batkai et al., 2023). Interestingly, we found that other potential sources of social pressure such as community elders, family members or media programs did not have a strong or significant influence farmers' decision-making. A possible explanation for this is that these sources might not be seen as directly relevant or relatable compared to peer farmers who share similar challenges and experiences. Also, the influence of others on farmers' decision-making process seems to depend on the socio-cultural context. For example, a study on farmers' tree planting in Malawi found only a weak effect of subjective norms on farmers' intentions (Meijer et al., 2015), whereas a study on agroforestry in Ethiopia found that pressure from significant others influenced farmers' intentions (Amare & Darr, 2022). These contrasting findings indicate that the influence of subjective norms on farmers' decision-making processes may vary across different regions and communities based on the local context. Understanding community dynamics and social interaction is also important due to potential disputes with neighbours, which might occur particularly with regard to boundary tree planting of economically preferred tree species that have negative ecological and economic impacts (Bala et al., 2020). Considering species selection aligned with local environmental and socio-cultural factors is thus critical when promoting tree diversification practices among farmers.

4.2 | Negative outcome expectations pose a barrier to tree diversification

Our study shows that farmers generally had positive attitudes toward tree diversification, valuing the multiple ecosystem services provided by trees and associating them with benefits such as mitigating climate change, increasing livelihood benefits, and promoting pollinator visitation. The positive attitudes and diversity of purposes of on-farm trees are consistent with findings from other studies across Sub-Saharan Africa (e.g. Horamo et al., 2020; Meijer et al., 2015). Yet, despite the overall positive attitudes toward tree diversification, specific concerns about negative consequences of growing more diverse tree species influenced smallholders' intention to diversify. Surprisingly, beliefs about the expected impacts of tree diversification on crop yields, livelihood benefits and climate were not statistically important in shaping farmers' attitudes. This might be attributed to the long-term nature of these expected benefits, as trees typically require many years to yield fruits or timber. Additionally, climate-related benefits are broad and long-term, often extending beyond the typical decision-making horizons of people. Interestingly, our analysis also showed no statistically important influence of distance to the forest on farmers' intentions. It might be that distance to forest influences farmers' use and management of tree resources in complex, potentially opposing ways. For example, being near a forest could increase farmers' knowledge and access to tree seeds and wildings, but simultaneously also reduce their need to plant trees on their farms as they can rely on forest resources.

Key formative beliefs for farmers' attitudes toward tree diversification were concerns about the risk of attracting harmful wildlife (such as insects, chameleons, and snakes) and potential negative implications for soil fertility. As the presence of forests and forest-like habitats is associated with wild animals, farmers' concerns about tree diversification might influence their decision-making. Human-wildlife conflict is a growing concern for smallholder farmers near forests in Sub-Saharan Africa, threatening the well-being and food

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security of subsistence farmers (e.g. Ango et al., 2017; Siljander et al., 2020). Yet, integrating diverse trees on farms can also attract wild animals that positively impact farmers' livelihoods and food security, such as insect pollinators and birds that provide pest control services (Albrecht et al., 2020; Delaney et al., 2020). Our findings highlight the importance of considering both perceived negative and positive outcomes of growing a more diverse mix of trees on smallholder farms.

While a meta-analysis found that agroforestry practices in Sub-Saharan Africa on average increase crop yield and soil fertility compared to non-agroforestry practices (Kuyah et al., 2019), the impact of trees in smallholder farms depends on various factors, including the species selection. For instance, a study in central Kenya found that soil conservation is one of the main reasons for farmers' conserving native tree species on their farms, while non-native tree species are planted for economic purposes such as income and fuelwood (Wawira & Thenya, 2017). Given the dominance of Eucalyptus trees across Vihiga (Imbaya et al., 2024) and with almost 80% of respondents reporting various negative consequences including soil acidification, nutrient depletion, and reduced soil moisture, it is likely that farmers associate the negative consequences of tree diversification with the effect of Eucalyptus trees. Encouraging the cultivation of native tree species alongside food crops can potentially mitigate concerns about soil fertility and contribute to the overall sustainability of smallholder farming systems. This emphasises the importance of assessing both negative and positive perceived impacts of tree diversification as these can impact farmers' intentions to diversify.

4.3 | Trade-offs between tree diversification and livelihood needs

Despite farmers' overall positive attitudes toward tree diversification, our results indicate that farmers' tree diversification behaviour may be constrained by more immediate short-term needs. We found that farmers in the wealthiest 20% of Kenya's rural population were more likely to diversify. Further, small farm sizes emerged as a key barrier, with the majority of the survey respondents (73%) farming on land smaller than 1 acre. As a result, farmers may prioritise immediate food security needs, focusing on the cultivation of staple crops such as maize and beans. Additionally, over 95% of our survey respondents relied on fuelwood for cooking, indicating that farmers might prioritise fast-growing tree species on their farms. While these priorities focus on ensuring short-term livelihood needs, this often comes at the expense of investing in the ecosystem services provided by trees, which might take several years to yield benefits. Our findings highlight the trade-offs farmers face between subsistence farming and tree diversification, reflecting results from prior research in similar contexts. Notably, studies in Ethiopia (Horamo et al., 2020) and Malawi (Meijer et al., 2015) have highlighted how factors like wealth, education, and land size influence farmers' tree growing decisions and how poverty can hinder the adoption of agroforestry until more immediate needs are met. Species selection should be tailored to the socio-economic context of smallholder farmers, as is implemented in decision support tools such as Diversity for Restoration (Fremout et al., 2022). In addition, providing farmers with direct financial incentives to enhance trees on farms specifically for ecosystem service delivery could also influence farmers' tree growing behaviour (www.myfarmtrees.org).

5 | CONCLUSION

Integrating diverse trees on smallholder farms has emerged as a promising nature-based solution to biodiversity conservation, climate change, and food security challenges (Ickowitz et al., 2022; Kuyah et al., 2019). Yet, a better understanding of farmers' decision-making in tree growing is crucial for realising the potential multifunctional benefits of agroforestry. Through a survey of 620 smallholders in Western Kenya, we aimed to explore the factors influencing farmers' decisions to diversify their farm trees. Our results highlight the complexity of farmers' decision-making, encompassing various socio-demographic and socio-psychological factors. We further identified key enablers and barriers that are crucial for promoting tree diversification. Future research should seek to expand on this by investigating context-specific barriers and enablers across other densely populated smallholder landscapes. Additionally, more research is needed to inform species selection of multi-purpose trees, exploring the socio-ecological suitability of native and non-native species. Ultimately, these insights can inform practices and policies that support a bottom-up approach to scaling up tree-based restoration efforts.

AUTHOR CONTRIBUTIONS

All authors conceived the ideas and designed the methodology; Ennia Bosshard analysed the data and led the writing of the manuscript; Chris Kettle obtained funding from the One CGIAR Nature+ initiative through the Alliance of Bioversity International and CIAT; All authors contributed critically to the drafts and gave final approval for publication.

ACKNOWLEDGEMENTS

We are grateful to all survey participants who kindly provided us with their time and insights. We also thank everyone who participated in our focus group discussions and pilot study, contributing to the refinement of our survey questionnaire. We owe special thanks to our local enumerators Truphosah Olukalie, Humphrey Mabiala, Laban Ikuua, Harrison Ambuko for their diligent efforts in conducting the farmer surveys. We thank the One CGIAR Nature+ initiative for funding support. This research was also supported by a doctoral scholarship provided by the Bakala Foundation to Ennia Bosshard.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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DATA AVAILABILITY STATEMENT

Anonymised data from the survey relating to the Theory of Planned Behaviour questions are available at https://doi.org/10.5061/dryad.mw6m90666.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Appendix 1: Preliminary work: Focus group discussions and pilot study.

Appendix 2: Guidelines for the Focus Group Discussions.

Appendix 3: Socio-demographic and farm characteristics.

Appendix 4: Farmer survey questionnaire (English version).

Appendix 5: Survey questionnaire (Kiswahili).

Appendix 6: Questionnaire variables.

Appendix 7: Data collection and sampling.

Appendix 8: Data analysis using PLS-SEM.

Appendix 9: Ordinal Logistic Regression.

Appendix 10: Qualitative Results.

How to cite this article: Bosshard, E., Carter, H., Aluso, L., Chumba, R., Kaiser-Bunbury, C. N., Kettle, C. J., & Nuno, A. (2025). Understanding smallholder decision-making to increase farm tree diversity: Enablers and barriers for forest landscape restoration in Western Kenya. *People and Nature*, *00*, 1–15. https://doi.org/10.1002/pan3.10774

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