Community-driven tree planting in Northern Namibia: Determinants and challenges

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Abstract. Climate change and environmental degradation are among the most pressing global issues, making tree planting initiatives essential for combating climate change, halting biodiversity loss, and restoring degraded landscapes. However, many tree planting programs face challenges such as planting non-native, potentially invasive species, and disregarding community preferences. Therefore, for successful tree planting programs, community input should be strongly considered, such as considering the multi-purpose trees' functionality and primary socioeconomic factors affecting tree planting. This paper examines the community preferences for native species, as well as household-level determinants and challenges affecting tree planting programs, utilizing a unique dataset from northern Namibia. Using a multilevel logistic regression model, we found that low-income households with larger landholdings are more likely to participate in tree planting initiatives. In contrast, households with members engaged in non-farm employment are less inclined to start or continue planting even when provided with seedlings, as they may prefer more stable and low-risk income streams. We recommend that future tree planting programs align with household preferences for tree purposes and provide sufficient economic incentives to ensure the sustainable maintenance of planted species.

1 Introduction

The threats of climate change and severe environmental degradation are among the most pressing global issues [1]. Several global initiatives, such as the European Green Deal and the Africa Green Wall, have promoted tree planting to combat climate change and desertification, halt biodiversity loss and to restore degraded landscapes [2, 3]. These approaches aim to replenish tree stocks by planting new trees or sowing seeds. Planting timber trees on degraded lands helps restore soil fertility, prevent erosion, and improve water

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retention [4]. At the same time, trees can also absorb carbon dioxide, therefore reducing greenhouse gas emission in the atmosphere. In light of this, timber tree plantations can serve as significant global carbon sinks [5].

Nevertheless, tree planting initiatives have also been plagued by several problems. Several planting initiatives have been found to plant non-native trees, which pose risks to the environment as these species could be invasive. These invasive species can outcompete local flora, thus altering native ecosystem functions [6]. Furthermore, some exotic plant species can change soil pH and nutrient availability, resulting in the disruption of the native plants growth in the vicinity [7]. Apart from biological implications, A study by [8] discussed the leading causes of failure in tree planting initiatives, namely the lack of community input and stakeholder's engagement, as well as the mismatch between the goals of local communities and restoration managers.

Our study addresses the challenge of limited practical guidance for tree planting initiatives by proposing actionable plans tailored to semiarid areas of Namibia—a region that has been underexplored in previous research. We contribute to current debates on the effectiveness of community-based tree planting methods, therefore enriching the literature on community activation strategies in northern Namibia. To achieve this, we conducted a baseline survey to study the community, investigating current household situation, farming preferences, and possible determinants and barriers to tree-planting. We then organized workshops to invite our targeted community members and provide them with training delivered by local experts and the Forestry district office. The training covered correct tree planting practices, as well as techniques supporting tree management such as composting and biochar. We will also distribute tree seedlings according to their preferences and monitor the growth of the trees periodically over one-year post-workshop.

Nevertheless, in this paper, we will focus on the findings from our baseline survey. Therefore, our research questions are: (1) What factors influence the prior awareness of tree planting techniques and composting within the community and (2) What household characteristics determine the chosen tree species for planting?

2 Methodology

2.1 Data and context

Our study is conducted in Ohangwena region of northern Namibia. The region experiences a semi-arid climate characterized by hot temperatures and low rainfall. It has predominantly sandy soils with low fertility and poor water-holding capacity. Communal land ownership is common, with customary authorities overseeing land harvesting to the members of the community. In Namibia, timber tree populations are over-exploited due to unsustainable harvesting and clearing of land for crop farming. At the same time, there is pressing environmental degradation due to drought and climate invariability. In the region, the planting of several native tree species has been promoted by the local district forestry offices, namely *Omuuva* (*Pterocarpus angolensis*), *Omushii* (*Guibourtia coleosperma*), and *Omupapa* (*Baikiae plurijuga*).

We conducted a baseline survey in July 2024 to collect background information on communities, including household characteristics, income, as well as perceived environmental indicators. We managed to collect 67 responses from three constituencies: Okongo, Omundaungilo, and Oshikunde. The areas are sparsely populated, which made it difficult to collect a larger sample size within the required timeframe. The GPS coordinates of this household are presented in Fig 1.

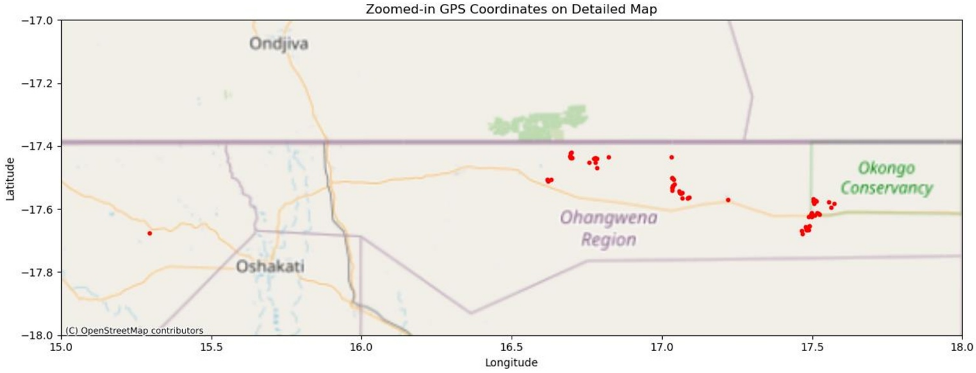

Fig. 1. GIS location of the surveyed household

2.2 Descriptive statistics

We reported the descriptive findings of the surveyed household in Table 1. In general, the majority of households are headed by females; with the average age of the household head being 56 years old. More than half possess upper primary education and above, and the average household size is 12. The majority also own livestock while at the same time doing subsistence farming, and have access to cultivated land and woodland. The average distance to reach the market is 20 minutes, and the distance to procure clear water –primarily using borehole wells– is a 19-minute walk. The households generally exhibit low social trust, and around half have not ever heard of composting and tree planting. Further, more than half of them also expressed interests in planting trees with varying function, with fruit trees being the most popular.

Table 1. Summary statistics of key variables

VARIABLE	Mean	SD	Min	Max	Count
Female head (=1 if Yes)	0.612	0.491	0	1	67
Age head	56.333	13.251	32	89	66
Head helping in farming (=1 if Yes)	0.925	0.265	0	1	67
Head has upper primary education and above (=1 if Yes)	0.627	0.487	0	1	67
Total no of household member	12.000	6.708	0	32	67
Size of all land (acre)	6.104	5.351	2	30	67
Source of land: Allocated by village head/traditional authority	0.776	0.420	0	1	67
Having livestock (=1 if Yes)	0.791	0.410	0	1	67
Access to cultivated land (=1 if Yes)	0.910	0.288	0	1	67
Access to woodland (=1 if Yes)	0.881	0.327	0	1	67

Table 1. Summary statistics of key variables (*continue*)

VARIABLE	Mean	SD	Min	Max	Count
Source of drinking water (in minutes walking distance)	19.746	21.425	1	120	67
Have ever received assistance from welfare office (=1 if Yes)	0.567	0.499	0	1	67
Distance (minutes walking) to Market	20.358	16.666	2	90	67
Distance (minutes walking) to Neighbor	4.940	3.200	1	20	67
Does your dwelling have a toilet or pit latrine? (Yes=1)	0.418	0.497	0	1	67
Do you think most people can be trusted? (Yes=1)	0.343	0.478	0	1	67
If given seedlings, would you plant and care of them (Yes=1)	0.642	0.483	0	1	67
Have heard of crop planting technology (Yes=1)	0.657	0.478	0	1	67
Have heard of composting technology (Yes=1)	0.493	0.504	0	1	67
Interested to plant fruit trees (Yes=1)	0.657	0.478	0	1	67
Interested to plant fodder trees (Yes=1)	0.552	0.501	0	1	67
Interested to plant timber trees (Yes=1)	0.627	0.487	0	1	67
Interested to plant medicinal trees (Yes=1)	0.642	0.483	0	1	67
Interested to plant shade trees (Yes=1)	0.642	0.483	0	1	67

2.3. Estimation strategy

Due to the sparse population in our studied region, there might be unobserved heterogeneity at the community level. In other words, our data might be hierarchical or nested at this level, thus the necessity to control for both fixed and random effects in the model. To examine the determinants of households' decisions to plant trees with specific traits, we employed a mixed-effects logistic regression model (see [9]), as follow:

$$logit\left(P\left(Y_{ij}=1\right)\right) = ln\, ln\, \left(\frac{P\left(Y_{ij}=1\right)}{1-P\left(Y_{ij}=1\right)}\right) = \alpha + \beta_1 X_{ij1} + \cdots + \beta_k X_{ijk} + u_j \quad (1)$$

$logit\left(P\left(Y_{ij}=1\right)\right)$ represents the log-odds that the dependent variable Y_{ij} equals 1 for $household_i$ in $community_j$, α is the fixed intercept, representing the baseline log-odds of the outcome when all independent variables are zero; $\beta_1, \dots, \beta_k$ are the fixed-effects coefficient for the independent variables $X_{ij1}, .., X_{ijk}$ that vary across households (e.g. education, access to market, land ownership, etc), while u_j is the random intercept for $community_j$, capturing community-specific effects that are not explained by the fixed predictors. The random component u_j is assumed to be normally distributed, with mean 0 and variance σ_u^2 :

$$u_j \sim N(0, \sigma_u^2) \quad (2)$$

In our model, we modeled the log-odds of selecting a particular tree trait as a function of household characteristics, including education, access to markets, distance to water sources, and land ownership variables. We also included a random intercept for each community to account for unobserved factors at the community level that could influence household decisions.

3 Results

3.1. Descriptive results

We reported information on household production from our baseline survey in Fig 2, showing that Mahangu (pearl millet), beans, maize, and sorghum are the most prevalent crops grown by households. These types of production are largely subsistence-based, with most of the output used for household consumption and only a small fraction sold. In Fig 3, for those who do sell their produce, the majority sell to local markets or neighbors.

Regarding the interest in planting trees for different purposes, the majority of respondents expressed high interests, particularly in fruit, medicinal, and shade trees, as shown in Fig 4. Additionally, we assessed interests in learning about supporting technologies for tree planting, namely composting and biochar in Fig 5. Most respondents expressed interest in learning more about these technologies, while the remaining responses were marked as N/A, indicating that were not familiar enough with these technologies to provide an answer.

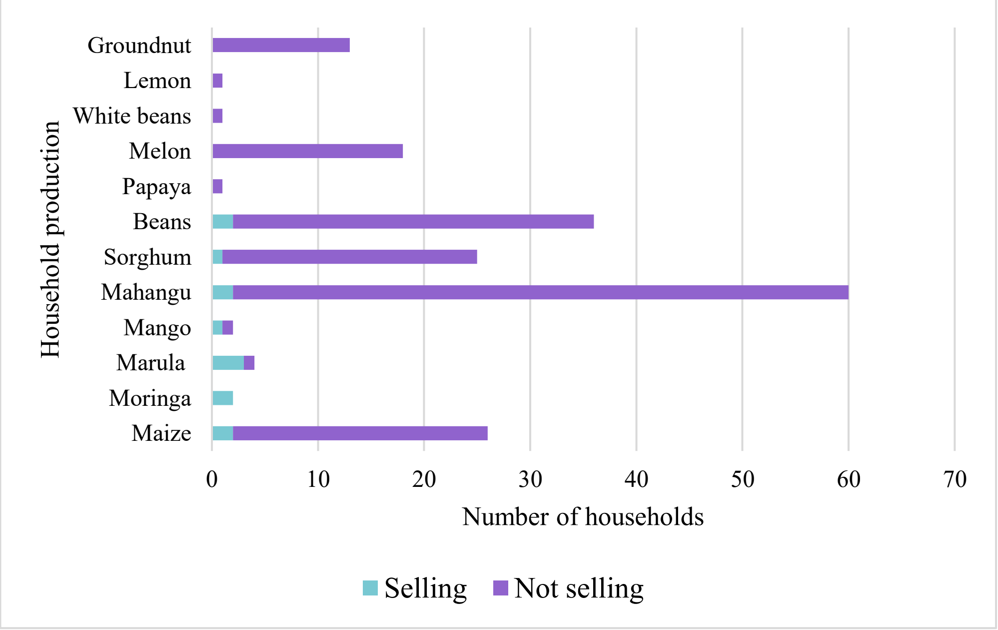

Fig. 2. Household farm production (source: author's data)

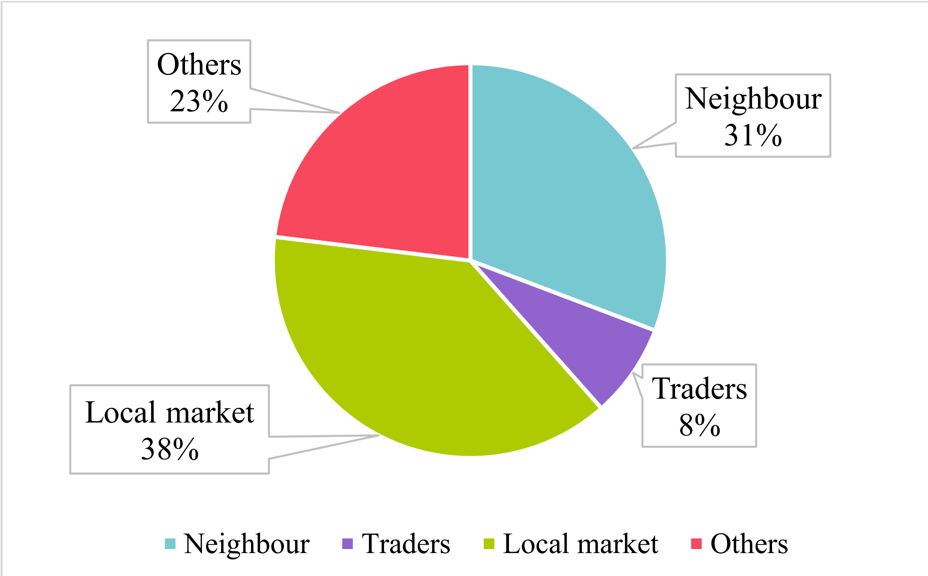

Fig. 3. Channels to sell the produce for those choosing to sell (source: author's data)

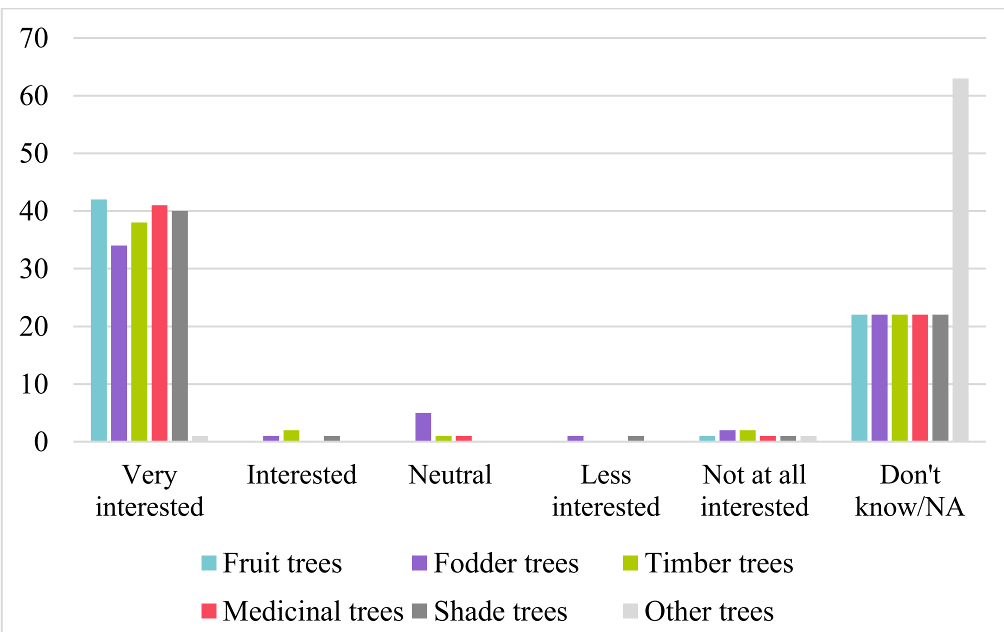

Fig. 4. Interest to plant tree species according to the purpose (source: author's data)

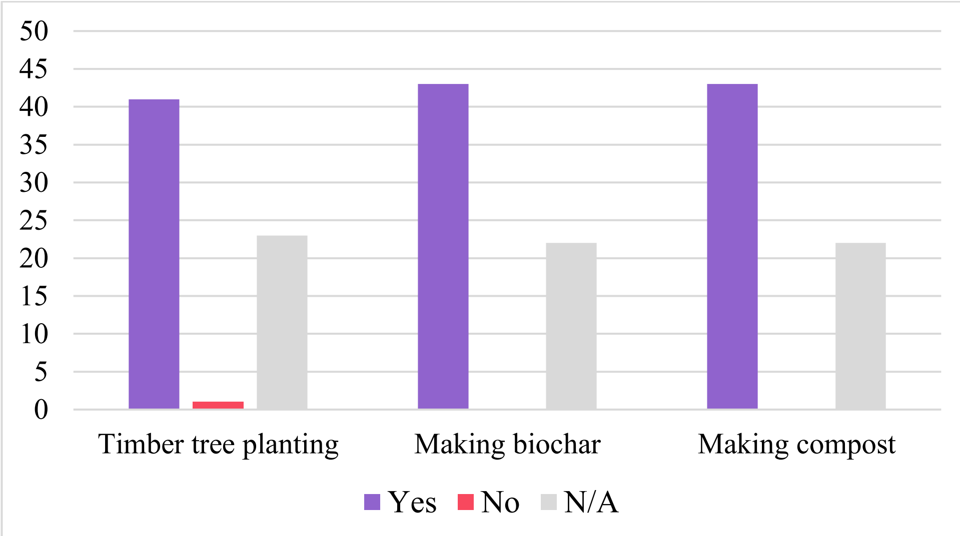

Fig. 5. Interest to learn tree planting, biochar, and composting (source: author's data)

3.2. Regression results

The regression results are shown in Table 2. In Column 1, the intention to grow trees if given seedlings is positively associated with being a welfare recipient household, and this relationship is consistent for other dependent variables, namely awareness of crop planting technologies (column 2), as well as the intention to grow types of trees for various purposes (column 4-7). On the other hand, non-farm job is negatively correlated with the intention to grow trees, suggesting that when households diversify their household income, tree planting tends to become less of a priority.

In terms of composting (column 3), the size of land in possession, the age of household head, and having migrant members within the household seemed to be positively correlated with the awareness of the technique. This suggests that more experienced and relatively wealthier household are more likely to be aware of composting, and that migrant members may potentially disseminate composting practices from outside to their household.

Furthermore, we found that relatively isolated household, indicated by less ease of access to their neighbors, are less likely to be interested in planting fodder and timber trees (column 5 and 6, respectively). Additionally, household with latrine facilities are more likely to be interested in planting medicinal trees (column 7), possibly due to higher health and hygiene awareness. Overall, we do not find significant effects of household head's education or walking distance to drinking water sources on these outcomes. This suggests that years of formal education do not directly influence interest in tree planting or preferences for the multipurpose functions of trees. Furthermore, while water scarcity may be a decisive factor in the Namibian context, it does not appear to be a major constraint in this case, as households seem to have access to public or communal borehole pumps near their homes.

Table 2. Determinants of planting propensity and interests

Dependent variables	(1) If given seedlings, would you plant and care of them (Yes=1)	(2) Have heard of planting technology (Yes=1)	(3) Have heard of composting technology (Yes=1)	(4) Interested in planting fruit trees (Yes=1)	(5) Interested in planting fodder trees (Yes=1)	(6) Interested in planting timber trees (Yes=1)	(7) Interested in planting medicinal trees (Yes=1)
Age of household head	-0.021	0.012	**0.074****	-0.003	0.011	-0.007	0.018
	(0.034)	(0.034)	(0.036)	(0.033)	(0.029)	(0.035)	(0.031)
Total no of household member	-0.102	**-0.154***	-0.068	-0.056	-0.039	-0.038	-0.050
	(0.078)	(0.079)	(0.061)	(0.060)	(0.055)	(0.058)	(0.057)
Size of all land (acre)	0.128	**0.155***	**0.152***	0.149	**0.155****	**0.166***	0.119
	(0.088)	(0.089)	(0.079)	(0.092)	(0.075)	(0.090)	(0.079)
Source of drinking water (in minutes walking distance)	-0.010	-0.007	0.006	-0.008	0.003	0.002	-0.005
	(0.017)	(0.018)	(0.016)	(0.016)	(0.015)	(0.020)	(0.015)
Received assistance from welfare office in the past 12 months (= 1 if Yes)	**2.704*****	**2.274****	0.689	**2.019****	**1.088***	**2.206****	**1.602****
	(1.012)	(0.971)	(0.683)	(0.924)	(0.631)	(0.990)	(0.697)
Distance (minutes walking) to Neighbor	0.053	-0.138	-0.137	-0.068	**-0.197***	**-0.237***	-0.129
	(0.180)	(0.169)	(0.142)	(0.163)	(0.115)	(0.130)	(0.140)
Other household member ever lived outside Ohangwena for more than 6 months (= 1 if Yes)	1.621	0.982	**2.501****	0.224	0.337	-0.542	0.435
	(1.362)	(1.315)	(1.208)	(1.033)	(0.900)	(1.028)	(0.976)
Members having non-farm income jobs (= 1 if Yes)	**-2.044***	-1.832	-0.242	-0.677	0.158	-0.778	-0.356
	(1.214)	(1.231)	(0.917)	(1.023)	(0.870)	(1.058)	(0.971)
Dwelling has a toilet or pit latrine (= 1 if Yes)	0.409	0.585	0.748	0.749	1.096	0.694	**1.370***
	(0.872)	(0.872)	(0.734)	(0.873)	(0.750)	(0.923)	(0.774)
Random effects at constituency level	2.682	1.277	0.000	0.871	0.000	1.028	0.000
	(3.211)	(2.004)	(0.000)	(1.514)	(0.000)	(1.709)	(0.000)
Observations	66	66	66	66	66	66	66
LR test vs. logistic model	4.02	1.13	-	14.38	13.57	14.38	14.38
Prob >= chibar2	0.0225	0.1444	0.0000000000003	0.0001	0.0001	0.0001	0.0001

Note: The result is based on mixed-effects logistic regression model. Gender of household head, education, land status (granted by village head), distance to market, Livestock possession (=1 if yes), head helping in farming in the past 12 months (=1 if yes), trustworthiness ("Would you say that other people can be trusted", =1 if Yes), and constant coefficients are not shown for brevity. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4 Conclusion and discussion

This paper examines the determinants of tree preferences in tree planting programs by identifying the main household characteristics influencing interests in tree planting. Employing a unique dataset from Northern Namibian context, we also perform descriptive analysis on households' farming activities and explored the interests on different multipurpose of preferred tree species. Using a mixed-effects logistic regression model, we found that low income households with relatively larger landholdings are more likely to be interested in tree planting initiatives. Additionally, households with migrant members may be more likely to receive information on planting or farming technologies from their host countries. However, household with members working in non-farm jobs may be less inclined to continue planting if provided with seedlings, as they may prefer easier and lower-risk income streams, such as wage or seasonal jobs. Household living in isolated areas, far from their neighbors, are also less likely to show interests in timber and fodder tree planting.

Our findings indicate that household socioeconomic characteristics and spatial factors play a critical role in shaping tree planting interests in Northern Namibia. The fact that low-income households with larger landholdings are more inclined to participate suggests that these households view tree planting as a long-term investment to enhance land productivity and diversify income sources. This finding aligns with (Feder et al., 1985), who posited that various household and farm-level factors—including income, landholding size, risk attitudes, and access to information—significantly influence adoption decisions. In particular, even though low income farmers face credit constraints, they can be more motivated to adopt new practices if the potential long-term benefit outweigh the risks.

Moreover, the increased likelihood of households with migrant members receive information on planting technologies underscores the role of migration networks in facilitating the diffusion of innovative technologies [10]. In contrast, households with members engaged in non-farm jobs might prefer income streams that require less labour and entail lower risks, thereby reducing their motivation to participate in labor-intensive tree planting initiatives.

Further, even though [11] showed that education has been a primary factor influencing successful agroforestry adoption, our results exhibit that formal qualification may not directly affect interest in tree planting or preferences for the multipurpose functions of trees. This finding corroborates [12] who demonstrated that socioeconomic factors and individual experiences often overshadow educational backgrounds in shaping willingness to engage in environmental activities such as tree planting. Our results further indicate that socio-economic characteristics are significant determinants of involvement in tree planting initiatives, with community involvement and household circumstances being more telling predictors of tree planting awareness than educational level alone.

Lastly, while water scarcity may be a decisive factor in the Namibian context, it does not appear to be a major constraint in our study, as households seem to have access to public or communal borehole pumps near their homes. Additionally, some native tree species may have developed species-specific adaptations to cope with limited water availability during drought. For instance, eucalyptus species, exhibit deep rooting strategies to access groundwater, thereby sustaining growth under drier conditions [13]. This finding suggests that there is rarely a one-size-fits-all approach to tree planting; selecting tree species in drought-prone areas may require careful consideration of species-specific water uptake traits, which may favour native trees over exotic species.

This study provides important insights for future tree planting initiatives. First, programs should consider household preferences (e.g. for fruit, medicinal, timber purposes) while also considering ecological aspects, such as prioritizing native tree species. Secondly, household income streams –whether farm or non-farm– may influence the propensity for tree planting, as planting interests tends to be associated with lower income levels. We acknowledge a limitation of our dataset: the small sample size may limit the generalizability of our findings. Future research using panel datasets is recommended to capture unobserved characteristics (such as the propensity for hard work), which would lead to a more robust model and analysis.

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