Agroforestry: Enhancing Farm Tree Diversity and its Role in Rural Livelihoods

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Abstract
Agroforestry represents a land use strategy grounded in ecological principles, offering benefits such as increased crop yields, consistent financial returns, and broader agricultural diversification. This study was conducted in Makawanpurgadhi rural municipality, from Makawanpur district, Nepal, which aimed to evaluate various agroforestry systems, the diversity of farm trees, and their impact on rural income. Field observation, interviews with key informants, and questionnaire survey were employed to augment socio-economic information, with a randomly selected sample of 106 households (i.e. Landowners). Farm tree diversity was assessed using the Shannon Wiener Diversity Index. The study identified five important agroforestry systems: homegarden, silvi-pasture, agrisilviculture, silvofisheries, and agrisilvihorticulture. The Silvi-pasture system reported as a promising agroforestry approach demonstrating greater species richness and diversity of farm tree compared to homegarden and agrisilvihorticulture. Moreover, agroforestry systems contributed significantly to household income, with 36.92% (NRS. 25,700 or USD 193 per household per year) attributed to agriculture and 28.88% (NRS. 16,900 or USD 127 per household per year) to livestock rearing. It is recommended that agroforestry systems have a great deal of potential to conserve biodiversity and enhance rural livelihoods.

Keywords
Agriculture; Farm land; Farm trees; Income; Agroforestry

1. Introduction

Reducing pressure on forests and expanding the environment beyond forest areas are primary objectives of recent government policies and initiatives. Agroforestry (AF) systems are considered a viable solution to address land management and ecological concerns while also meeting the demands of a growing population and crop diversity (FAO 2003; Salinas, 2016; Schnell et al., 2015). It integrates forestry, agriculture, and other land uses into the same unit of land to safeguard the production of diverse ranges of products and services while promoting enhanced environmental sustainability (Paudel et al., 2019; Reed et al., 2017; Shin et al., 2020). In Nepal, AF plays a critical role in
producing food, fuel, timber, and other minor forest products, thereby generating income for underprivileged communities and contributing to environmental conservation (Amatya, Cedamon and Nuberg, 2018; Paudel et al., 2019).

AF is an approach to land management that offers eco-agricultural solutions by integrating goals for improved food security with benefits in biodiversity conservation, particularly through promoting the use of native tree species (Acharya, 2006; Atta-Krah et al., 2004; Reed et al., 2017). Trees in and around agricultural lands provide valuable goods and services to communities. Agroforestry systems are critical for preserving and restoring the physical environment. They play an important role in reducing erosion, enriching soil fertility, reducing pollution, and promoting biodiversity conservation (Acharya, 2006; Atta-Krah et al., 2004; Ojha et al., 2022). Soil fertility degradation, increased soil erosion, and decreased agricultural output have all been linked to declines in forest cover. Agroforestry shows promise as a solution to address these issues (Amatya, Cedamon and Nuberg, 2018; Carter and Gilmour, 1989; Paudel et al., 2019). Studies worldwide indicate advancements in tree growth on private farmlands to counter the loss of forest trees (Baral et al., 2013; Ghimire and Bolakhe, 2020; Kang and Akinnifesi, 2000; Thapa et al., 1994).

Agriculture has historically served as the primary source of income across the Nepalese hills, with subsistence agriculture forming the backbone of economic activity in this region, closely intertwined with forest resources. These small-scale farming systems have traditionally relied on forest products, which provide a diverse array of goods and services crucial for both biodiversity conservation and subsistence (Acharya, 2006; Nupane et al., 2002; Ojha et al., 2022). Agroforestry is a multidimensional approach to sustainable land management that offers numerous advantages for both rural communities and biodiversity conservation. Because of this, it has garnered considerable attention from conservation scientists seeking innovative solutions to environmental challenges (Acharya and Kafle, 2009; McNeely and Schroth, 2006; Ojha et al., 2022). Despite this potential, Nepal's agricultural and forestry development plans have historically placed little emphasis on promoting agroforestry (Amatya, Cedamon and Nuberg, 2018). However, recent years have seen increased recognition of agroforestry's crucial role in sustaining rural agriculture, leading to initiatives aimed at promoting agroforestry at the farm level. While the focus has traditionally centered on trees within forests, those outside forested areas or on farms in Nepal represent vital resources for enhancing sustainable development and livelihoods. Furthermore, despite their significant contributions to human well-being and environmental preservation, trees on farmland and in various land use types around human settlements have not been systematically integrated into the national forest inventory (DFRS, 2015; Ghimire et al., 2021).

In this backdrop, this study primarily aims to evaluate farm tree diversity and its impact on rural livelihood enhancement.

2. Materials and Methods

2.1 Study Area

This research was conducted in ward number 6 of Makawanpurgadh rural municipality, located in Makawanpur district, Nepal (Figure 1). This municipality shares borders with Bakaiya rural municipality to the east, Uchita Lamichhane, Pramod Ghimire
Bhimphedi rural municipality to the west and north, and Hetauda Sub-metropolitan City to the south. Topographically, the district spans from 27°10' to 27°40' latitude and 84° 41' to 85°31' longitudes, with Makawanpur rural municipality situated 34 km south of Kathmandu and 17 kilometers north of Hetauda city. The area experiences a tropical to subtropical climate, characterized by an average annual temperature of 28 degrees Celsius and approximately 240 mm of rainfall. Geologically, the region represents the upper Chure range and lower Mahabharat Hill's alternate strata, consisting of shale, schist, quartzite, and phyllite, alongside limestone beds, and various granite and gneiss (Bajracharya et al., 2007; MRM, 2023). Agriculture and livestock farming are the primary occupations in this area.

Figure 1: Map illustrating the study area

2.2 Sampling Method and Data Analysis

The research employed both qualitative and quantitative approaches to investigate the existing agroforestry system, tree diversity, and its contribution to local livelihood improvement. For the vegetation survey, circular plots (n=43) of size 1,000 m² with a radius of 17.84m were purposively laid out according to the prevalent agroforestry systems. During the vegetation survey of the household farm sample, all tree species and the number of individuals within each plot were counted. Subsequently, farm tree diversity was determined applying the Shannon-Wiener index, which considers both the evenness and abundance of the species present (Maturin, 1988). Shannon-Wiener index is represented by $H$, which is determined as:

$$H = -\sum P_i \times \ln P_i$$

Where, $H$ = Shannon-Wiener index,

Similarly, the term evenness is represented by $E$, which is calculated as:

$$E = H / \ln S$$

Where, $E$ = evenness,

$H$ = The Shannon Diversity Index,

$S$ = Total number of species within the community.
For socio-economic data analysis, a questionnaire survey was conducted on 106 farm households (including those from sample plot located households and adjoining households) to augment necessary information. Additionally, to validate and cross-check the data from the household survey, 3 focus groups and 23 key informant interviews were conducted. The collected data were analyzed using SPSS and presented through tables, graphs, figures, and charts to facilitate logical interpretation.

3. Results

3.1 Agroforestry Systems Adopted

In a given ecosystem, tree diversity plays a critical role in maintaining natural environmental equilibrium. This becomes particularly crucial in areas where natural forest encroachment and land degradation are diminishing biodiversity, potentially resulting in the loss of the natural ecosystem. This study reported five major agroforestry systems: homegarden, silvipasture, agrisilviculture, silvofisheries, and agrisilvihorticulture (Table 1). A survey of 106 household farms revealed that the majority of households adopted homegardens (58%), followed by silvipasture (41%), agrisilviculture (16%), silvofisheries (9%), and agrisilvihorticulture (4%). Homegardens are primarily adopted by households to fulfill their nutritional needs, ensure food security, preserve agrobiodiversity, and promote environmental sustainability.

Table 1: Agroforestry systems and species combinations

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Types of Agroforestry System</th>
<th>Description</th>
<th>Major Species Combination</th>
<th>Percentage of HHs used</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Homegarden</td>
<td>Growing cereals, vegetable spices with firewood, and fodder species.</td>
<td>Mangifera indica, Atrocarpus heterophalus, Persea americana, along with banana, pineapples, chili, turmeric, and vegetable species.</td>
<td>47%</td>
</tr>
<tr>
<td>2.</td>
<td>Silvipasture</td>
<td>Raising forest trees with livestock in the same land.</td>
<td>Litsea monopetala, Ficus sp., Bauhinia sp., grasses and livestock in rain faded land or fallow land.</td>
<td>24%</td>
</tr>
<tr>
<td>3.</td>
<td>Agrisilviculture</td>
<td>Cultivating seasonal agricultural crops along with mixed tree species.</td>
<td>Tectona grandis, Dalbergia sissoo, Eucalyptus camaldulensis, Albizia lebbek along with agricultural crops (such as Turmeric and ginger).</td>
<td>16%</td>
</tr>
<tr>
<td>4.</td>
<td>Silvofishery</td>
<td>Fish farming in conjunction with forest tree species.</td>
<td>Mangifera indica, Dalbergia Sissoo, Eucalyptus camaldulensis, Bauhinia variegata,</td>
<td>9%</td>
</tr>
<tr>
<td>S.N.</td>
<td>Types of Agroforestry System</td>
<td>Description</td>
<td>Major Species Combination</td>
<td>Percentage of HHs used</td>
</tr>
<tr>
<td>------</td>
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</tr>
<tr>
<td>5.</td>
<td>Agrisilvihorticulture</td>
<td>Growing agricultural crops alongside horticulture plants and forest trees.</td>
<td><em>Litsea monopetala</em> on the riser of the fish ponds, Fruit–trees (such as banana, mango), along with agricultural crops alongside <em>Eucalyptus camaldulensis</em>, <em>Dalbergia Sissoo</em>.</td>
<td>4%</td>
</tr>
</tbody>
</table>

### 3.2 Diversity and Abundance of Species across various Agroforestry Systems

A total of 71 tree species were documented in the study site. Among these, *Mangifera indica*, *Atrocarpus heterophalus*, *Litsea monopetala*, *Artocarpus lakoocha*, and *Shorea robusta* emerged as the major tree species found on farmland (Figure 2). The two most abundant tree species planted on farmland were *Mangifera indica* and *Artocarpus heterophyllus*. Additionally, the tree diversity index and species richness were also estimated for every agroforestry system under the study, as detailed in Table 2. The silvipasture system demonstrated the higher diversity index and species richness as compared to homegardens and agrisilvihorticulture, respectively. The silvipasture system emerged as the most diverse agroforestry system adopted, highlighting its preference and variability within the Makawanpurgadh rural municipality.

![Figure 2: Frequency of farm tree species occurrence](image-url)

### 3.3. Different Sources of Income of Studied Households

The socioeconomic data of 106 farm households was analyzed through a questionnaire survey to determine how much agroforestry systems contribute to rural livelihoods. Among the 106 farm households surveyed, 69 were male respondents and 37 were female respondents (Table 3). Additionally, 61.32% of...
the households were engaged in agriculture-related occupations, while 38.68% relied on non-agricultural occupations, including government and private services (Table 3). Furthermore, the average annual income of the households was determined to be NRS. 170,990 (equivalent to USD 1,286), with the majority of households (43) falling into the category with an annual income of less than NRS. 150,000 (equivalent to USD 1,128) (Table 3).

Table 2: Species richness and farm tree diversity across various agroforestry systems

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Agroforestry Systems</th>
<th>Species richness</th>
<th>Shannon Weiner Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Homegarden</td>
<td>26</td>
<td>0.37</td>
</tr>
<tr>
<td>2.</td>
<td>Silvipasture</td>
<td>38</td>
<td>0.62</td>
</tr>
<tr>
<td>3.</td>
<td>Agrisilviculture</td>
<td>15</td>
<td>0.24</td>
</tr>
<tr>
<td>4.</td>
<td>Silvofishery</td>
<td>7</td>
<td>0.10</td>
</tr>
<tr>
<td>5.</td>
<td>Agrisilvihorticulture</td>
<td>21</td>
<td>0.30</td>
</tr>
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</table>

Table 3: Socio-economic attributes of studied households

<table>
<thead>
<tr>
<th>Class</th>
<th>Attributes</th>
<th>Number</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Male</td>
<td>69</td>
<td>65.10</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>37</td>
<td>34.90</td>
</tr>
<tr>
<td>Occupation</td>
<td>Agriculture</td>
<td>65</td>
<td>61.32</td>
</tr>
<tr>
<td></td>
<td>Government services</td>
<td>22</td>
<td>20.76</td>
</tr>
<tr>
<td></td>
<td>Private services</td>
<td>19</td>
<td>17.92</td>
</tr>
<tr>
<td>Annual income</td>
<td>&lt;150,000 (&lt;USD 1,128)</td>
<td>43</td>
<td>40.57</td>
</tr>
<tr>
<td></td>
<td>150,000-200,000 (USD 1,128-1,504)</td>
<td>37</td>
<td>34.90</td>
</tr>
<tr>
<td></td>
<td>&gt;200,000 (&gt;USD 1,504)</td>
<td>26</td>
<td>24.53</td>
</tr>
</tbody>
</table>

3.4 Farm Trees’ Contribution to the Agricultural and Livestock Income

Agroforestry is a land management strategy in which parts of forestry and agriculture are combined to provide a variety of benefits, including fuelwood, timber, food, fodder, and other agricultural and forestry-related goods and services within a given area and time frame. Respondents were queried regarding their overall income as well as the relative contributions of different income sources. According to the study findings, out of the average net annual household income, income from agriculture and livestock constituted 40.70% and 34.21%, respectively. Furthermore, the adopted agroforestry systems in the study area contributed 36.92% (NRS. 25,700, equivalent to USD 193, per household per year) and 28.88% (NRS. 16,900, equivalent to USD 127, per household per year) to the agricultural income and income from livestock farming, respectively (Figure 3).

4. Discussion

Agroforestry is not a novel practice; rather, it is emerging as a science. The objective of agroforestry development in Nepal is to mitigate environmental degradation while also fulfilling the demand for fodder, non-wood forest
products, fuelwood, and small timber, including aromatic and medicinal plants, both now and in the future (Amatya, Cedamon and Nuberg, 2018). Although, agroforestry practice has long been a longstanding part of traditional farming techniques in Nepal, they have also been shown to harbor higher biodiversity than Nepalese forests and provide farmers with additional market alternatives (Acharya, 2006). This study identified five major agroforestry systems, with the majority of households preferring homegardens due to their immediate access to fresh produce (Table 1). In terms of tree diversity, silvipasture systems demonstrated the higher species richness and diversity index, with home gardens and agrisilviculticulture coming in second and third, respectively (Table 2). Nepal’s agroforestry system has become increasingly diverse due to the country’s growing commercialization and abandonment of agricultural land (Ulak et al., 2021). The farmer-led approach is undeniably one of the most significant strategies for increasing tree cover in rural agriculture. This finding is in line with Ghimire and Bolakhe (2020) and Khanal (2011) who reported greater tree diversity and species richness in silvipasture systems in Makawanpur and Kaski districts, respectively. However, Baral et al. (2013) found that homegarden in the Kanchanpur district of Nepal exhibited higher tree diversity and species richness compared to agrisilviculture. The differences in results can be accounted to variations in geographic regions, which differ depending on the location within a specific zone. Nonetheless, it is evident how agroforestry techniques enhance farm tree diversity and contribute to environmental restoration.

Agroforestry strategy play a critical role in addressing hunger, improving local livelihoods, conserving biodiversity, and bolstering institutional and societal adaptability to climate change (Mbøy et al., 2014). In Nepal, agriculture remains the primary means of income for the majority of the population, with approximately 70% still engaged in agricultural activities (FAO, 2023; GC and Hall, 2022). Rural farmers rely on farmland to meet their daily needs, with the average per capita income (PCI) in Nepal standing at NPR.
186,067 annually (equivalent to USD 1,399) (CEIC Data, 2023). A significant portion of households (61.32%) in the study area were engaged in agricultural activities (Table 3). The average annual income of households was determined to be NRs. 170,990 (equivalent to USD 1,286). Of the total average net annual household income, income from agriculture and livestock constituted 40.70% and 34.21%, respectively. Notably, agroforestry systems contributed 36.92% and 28.88% to agriculture income and livestock income, respectively. According to the Agroforestry Network (2018), nine of the seventeen Sustainable Development Goals (SDGs) can be addressed through agroforestry. Of these, nine have the potential to be addressed through agroforestry, with a particular emphasis on goals including No poverty; Zero hunger; Climate action; and Life on land. This indicates the significance of agroforestry systems for improving local livelihoods in Nepalese context. These findings are consistent with those of Ghimire and Bolakhe (2020), who documented that in the Makawanpur district, agroforestry systems contributed 24.06% and 20.25%, respectively, to agricultural income and income from livestock rearing. In Kanchanpur district, similar results were also observed by Baral et al. (2013) where farm trees contributed 16.4% and 17.1% to agricultural income and income from livestock rearing, respectively. Therefore, agroforestry holds immense potential to uplift rural livelihoods by reducing local communities' dependence on forest resources.

5. Conclusions

A total of 71 farm tree species were documented across the five different agroforestry systems studied. Greater diversity index and species richness for farm tree were observed in Silvipasture, compared to homegarden and agrisilvihorticulture, respectively. Agroforestry in the study site contributed 36.92% and 28.88% to agriculture income and livestock income per household per year, respectively. These findings show the importance of suitable trees planted outside of forests can support rural communities' livelihoods and biodiversity. Future local and national forest sector strategies must take these resources into consideration, because trees outside of forests are essential for the upliftment of livelihoods of the local people.

6. Acknowledgements

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7. References


Acharya, K.P. (2006). Linking trees on farms with biodiversity conservation in


Authors’ Declarations and Essential Ethical Compliances

Authors’ Contributions (in accordance with ICMJE criteria for authorship)

<table>
<thead>
<tr>
<th>Contribution</th>
<th>Author 1</th>
<th>Author 2</th>
</tr>
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<td>Conceived and designed the research or analysis</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Collected the data</td>
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<td>No</td>
</tr>
<tr>
<td>Contributed to data analysis and interpretation</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Wrote the article/paper</td>
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<tr>
<td>Critical revision of the article/paper</td>
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<td>Editing of the article/paper</td>
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<tr>
<td>Supervision</td>
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<td>Project Administration</td>
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<td>Funding Acquisition</td>
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<td>Overall Contribution Proportion (%)</td>
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<td>30</td>
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Research involving human bodies or organs or tissues (Helsinki Declaration)
The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not a clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

Research involving animals (ARRIVE Checklist)
The author(s) solemnly declare(s) that this research has not involved any animal subject (body or organs) for experimentation. The research was not based on laboratory experiment involving any kind animal. The contexts of animals were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of ARRIVE does not apply in cases of this study or written work.

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The author(s) solemnly declare(s) that this research has not involved any Indigenous Peoples as participants or respondents. The contexts of Indigenous Peoples or Indigenous Knowledge were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) and Self-Declaration in this regard are appended.

Research involving Plants
The author(s) solemnly declare(s) that this research has involved the plants for experiment or field studies. Some contexts of plants are also indirectly covered through literature review. Thus, during this research the author(s) obeyed the

Research Involving Local Community Participants (Non-Indigenous) or Children
The author(s) solemnly declare(s) that this research has directly involved local community participants or respondents belonging to non-Indigenous peoples. But, this study did not involve any child in any form directly. The contexts of different humans, people, populations, men/women/children and ethnic people are only indirectly covered through literature review. A sample copy of the Consent Form implying prior informed consent (PIC) of the respondents is appended.

(Optional) PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)
The author(s) has/have NOT complied with PRISMA standards. It is not relevant in case of this study or written work.

Competing Interests/Conflict of Interest
Author(s) has/have no competing financial, professional, or personal interests from other parties or in publishing this manuscript. There is no conflict of interest with the publisher or the editorial team or the reviewers.

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To see original copy of these declarations signed by Corresponding/First Author (on behalf of other co-authors too), please download associated zip folder [Declarations] from the published Abstract page accessible through and linked with the DOI: https://doi.org/10.33002/aa030202
INFORMATION AND CONSENT FORM FROM RESPONDENTS
(Non-Indigenous or Indigenous Respondents)
*This form was translated into local language for the respondents*

Title of the Research: Agroforestry: Enhancing Farm Tree Diversity and its Role in Rural Livelihoods

Principal Researcher: Uchita Lamichhane
Faculty of Forestry, Agriculture and Forestry University,
Hetauda-10, Makawanpur district, Bagmati Province, Nepal

Research Supervisor: Pramod Ghimire
Faculty of Forestry, Agriculture and Forestry University,
Hetauda-10, Makawanpur district, Bagmati Province, Nepal

A) INFORMATION TO PARTICIPANTS

1. Objectives of the research
   The objectives of this study were to evaluate various agroforestry systems, farm tree diversity, and their contribution on rural income.

2. Participation in research
   The researcher will ask you several pertinent questions. This interview will be recorded in written form and should last about 50-60 minutes. The location and timing of the interview will be determined by you, depending on your availability and convenience.

3. Risks and disadvantages
   There is no particular risk involved in this project. You may, however, refuse to answer any question at any time or even terminate the interview.

4. Advantages and benefits
   You will receive intangible benefits even if you refuse to answer some questions or decide to terminate the interview. You will also contribute to a better understanding on how farm trees promotion can transform rural livelihoods.

5. Confidentiality
   Personal information you give us will be kept confidential. No information identifying you in any way will be published. In addition, each participant in the research will be assigned a code and only the researcher will know your identity.
6. Right of withdrawal
Your participation in this project is entirely voluntary and you can at any time withdraw from the research on simple verbal notice and without having to justify your decision, without consequence to you. If you decide to opt out of the research, please contact the researcher at the telephone number or email listed below. At your request, all information concerning you can also be destroyed. However, after the outbreak of the publishing process, it is impossible to destroy the analyses and results on the data collected.

B) CONSENT

Declaration of the participant
⇒ I understand that I can take some time to think before agreeing or not to participate in the research.
⇒ I can ask the research team questions and ask for satisfactory answers.
⇒ I understand that by participating in this research project, I do not relinquish any of my rights, including my right to terminate the interview at any time.
⇒ I have read this information and consent form and agree to participate in the research project.
⇒ I agree that the interviews be recorded in written form by the researcher: Yes (   ) No (   )

Signature of the participant : __________________________ Date : __________________________

Surname : __________________________ First name : __________________________

Researcher engagement
I explained to the participant the conditions for participation in the research project. I answered to the best of my knowledge the questions asked and I made sure of the participant's understanding. I, along with the research team, agree to abide by what was agreed to in this information and consent form.

Signature of the researcher : __________________________ Date : 13-06-2023

Surname: Lamichhane First name: Uchita

⇒ Should you have any questions regarding this study, or to withdraw from the research, please contact Ms. Uchita Lamichhane by e-mail uchitalamichhane@afu.edu.np

⇒ If you have any concerns about your rights or about the responsibilities of researchers concerning your participation in this project, you can contact the Pramod Ghimire, Faculty of Forestry, Agriculture and Forestry University, Hetauda-10, Makawanpur district, Bagmati Province, Nepal by e-mail pghimire@afu.edu.np