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FACULTY OF AGRICULTURE AND FORESTRY

# **Comparative analysis of floristic diversity and stand structure in different forest categories and socio-ecological implications on forests in Laos**



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<p>Laos is regarded as one of the world's biodiversity hotspots. Yet, like in many tropical countries, biodiversity in Laos has been decreasing at an alarming rate. Forest degradation and deforestation have led to many flora and fauna species becoming threatened or even extinct. Furthermore, they have also had detrimental impacts on ecosystem services, compromising human safety and well-being. This research aimed to investigate the floristic diversity and forest structure across different Lao forest categories and understand the socio-ecological implications on forests in Laos.</p> <p>The research was divided into three segments: a forest inventory, interviews with local people within two villages, and an interview with a local forest officer. The forest inventory was conducted in three different forest categories: conservation, protection, and production forests in Luang Prabang Province, using systematic plot sampling. The total sampling size was 1.2 hectares within 60 plots, 20 in each forest site, each plot measuring 200 m<sup>2</sup>. Furthermore, the interviews with the local people were conducted as focus group discussions in villages near the inventory sites, and the forest officer was interviewed in the city of Luang Prabang. These interviews aimed to understand how socioeconomic and other social factors influence the forests and conservation efforts.</p> <p>The study found significant differences between the forest categories. The conservation and protection forests shared similarities both structurally and in terms of species composition but were different from the production forest. Moreover, the woody and climber species richness were significantly lower in the production forest compared to the two other forest categories.</p> <p>The interviews revealed that the local people depend on access to forests and forest products, but the low-income households were particularly reliant on them. The study also found that even if the local people had positive attitudes towards forest conservation, the lack of alternative livelihood opportunities and insufficient funding are the primary barriers to effective conservation efforts.</p> <p>These findings highlight the need to address the diversity differences between the forest categories through adequate forest planning and management. However, this requires funding, which proved to be one of the critical factors in achieving more effective and sustainable forest management in Laos. The findings also underscore the urgency of addressing socio-economic factors in conservation planning. The study found that diversifying livelihood opportunities is crucial for forest sustainability and human well-being. Future conservation initiatives should enhance socio-economic aspects and the well-being of local people in addition to caring for the environmental aspects. This integrated approach ensures the sustainability of both natural ecosystems and local livelihoods, increasing the potential for sustainable and long-term positive outcomes.</p>			
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<p>Laosia pidetään yhtenä maailman monimuotoisuuskeskuksena. Tästä huolimatta, kuten usean muunkin trooppisen valtion kohdalla, Laosin biologinen monimuotoisuus on heikentynyt hälyttävällä vauhdilla. Metsien köyhtyminen ja metsäkato ovat ajaneet useat kasvi- ja eläinlajit uhanalaisiksi. Tämän lisäksi luonnon monimuotoisuuden köyhtymisellä on haitallisia vaikutuksia ekosysteemipalveluihin, ja sitä kautta myös ihmisten turvallisuuteen ja hyvinvointiin. Tämä tutkimus pyrki selvittämään Laosin metsäluokkien kasvilajiston monimuotoisuuden ja metsärakenteen eroja, sekä ymmärtämään metsiin kohdistuvia sosioekologisia vaikutuksia Laosissa.</p> <p>Tutkimus on jaettu kolmeen osaan: metsäinventointi, paikallisten ihmisten haastattelu kahdessa eri kylässä, ja paikallisen metsävirkamiehen haastattelu. Metsäinventointi suoritettiin kolmessa eri metsäluokassa: suojele-, suoja- ja tuotantometsässä Luang Prabangin maakunnassa. Inventointiossa käytettiin systemaattista näytteenottoa. Näytteenottokoko oli yhteensä 1,2 hehtaaria, yhteensä 60 koealan sisällä, eli jokaisessa tutkimusmetsässä oli 20 koealaa, ja kunkin koealan koko oli 200 m<sup>2</sup>. Paikallisten ihmisten haastattelut käytiin fokusryhmäkeskusteluina inventointimetsien läheisyydessä olevissa kylissä, ja metsävirkamiestä haastateltiin Luang Prabangin kaupungissa. Haastattelut pyrkivät ymmärtämään, miten sosioekonomiset ja muut sosiaaliset tekijät vaikuttavat metsiin ja suojeletoimiin.</p> <p>Tutkimuksessa havaittiin, että metsäluokkien välillä on merkittäviä eroja. Suojele- ja suojametsällä oli yhtäläisyyksiä sekä rakenteellisesti että lajikoostumukseltaan, ja ne erosivat merkittävästi tuotantometsästä. Lisäksi puu- ja köynnöskasvilajiston rikkaus olivat tuotantometsässä huomattavasti alhaisempia verrattuna kahteen muuhun metsäluokkaan.</p> <p>Haastatteluista kävi ilmi, että paikalliset ihmiset ovat riippuvaisia metsistä ja metsätuotteiden saatavuudesta. Tämä koskee erityisesti pienituloisia kotitalouksia. Tutkimuksessa todettiin myös, että vaikka paikalliset ihmiset suhtautuivat myönteisesti metsien suojeleluun, vaihtoehtoisten toimeentulomahdollisuuksien puute ja riittämätön rahoitus ovat ensisijaisia esteitä tehokkaalle luonnonsuojelutyölle.</p> <p>Tämän tutkimuksen tulokset korostavat tarvetta käsitellä metsäluokkien välisiä monimuotoisuuseroja metsien asianmukaisen suunnittelun ja hoidon avulla. Tämä vaatii rahoitusta, mikä osoittautui yhdeksi avaintekijäksi tehokkaamman ja kestävämmän metsänhoidon saavuttamiseksi Laosissa. Lisäksi tuloksista korostuu, että sosioekonomisten tekijöiden huomioiminen on kriittistä luonnonsuojelun suunnittelussa. Tutkimuksessa todetaan, että toimeentulomahdollisuuksien monipuolistaminen on ratkaisevan tärkeää sekä metsien kestävyden että ihmisten hyvinvoinnin kannalta. Suojelualoitteiden tulee edistää ympäristönäkökohdista huolehtimisen lisäksi sosioekonomisia olosuhteita ja paikallisten ihmisten hyvinvointia. Tämä integroitu lähestymistapa edistää luontaisten ekosysteemien ja paikallisten elinkeinojen kestävyttä, sekä mahdollistaa kestäviä ja myönteisiä lopputuloksia pitkällä aikavälillä.</p>		
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## **PREFACE**

When the opportunity arose to conduct my thesis research in Laos, one of the world's biodiversity hotspots facing a significant decline in biodiversity, I approached it with great excitement, a sense of purpose, and hope to make a meaningful contribution. Throughout my studies, I have become passionate about the complex interplay between human societies and their surrounding environment. In light of this fascination, this research aims to enrich our comprehension of the forest landscape and the relationship between the local people and the forests in Laos.

This thesis is structured first to explore key facets of biodiversity conservation within Laos. Initially, it examines the current status and threats to biodiversity, underscoring the importance of preserving ecological richness. Subsequently, attention turns to the classification of forest categories in Laos and the regulatory frameworks governing their management, contextualising the thesis topic.

After presenting the research topic, the study introduces the study sites and methodological approaches employed. This includes outlining the forest inventory and interview designs implemented during fieldwork conducted in northern Laos between January and March 2023. Subsequently, the research transitions to presenting the results, followed by an in-depth discussion, conclusions, and references. Finally, the inventory and interview forms are provided as supplementary materials in the appendices.

With this research, I seek to deepen our understanding of the floristic diversity between the Lao forest categories, highlight the interconnectedness between human and environmental systems, identify conservation needs, and offer suggestions for future conservation efforts in Laos and other developing countries.

I am incredibly grateful to the Viikki Tropical Resources Institute (VITRI) for giving me the opportunity, partial funding through the Erasmus+ programme, and open hands to

conduct my research. Moreover, I am indebted to my supervisor, Eshetu Yirdaw, for his unwavering support, invaluable insights, and mentorship throughout this journey. I also want to thank the VITRI coordinator, Dipjoy Chakma, and other VITRI staff who believed in my abilities and made it possible for me to embark on this journey. Their belief in me has been instrumental in shaping the direction of this research.

In addition to the Erasmus+ programme funding, this research would not have been possible without the financial support from the Finnish Cultural Foundation and the Metsämiesten Säätiö Foundation. Their generous financial contributions made this research endeavour feasible, and I sincerely appreciate their support.

Furthermore, I am deeply grateful for the collaboration with local specialists in the field, without whom the fieldwork would not have been possible. The forest inventory was conducted with Vone Inthasone, Siengmung Boobphaa, and Khamphieng Lattanaphone. Additionally, I thank Bounxian Phetlumphan and Phonepasith Phongdala from Souphanouvong University for their invaluable assistance with the interviews and translation work. I want to express my sincere gratitude to everyone I had the privilege of working with. I truly appreciate their expertise and generous support.

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Emmi Kaislasalmi

1<sup>st</sup> of May 2024,

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## LIST OF ABBREVIATIONS

Abbreviation	Definition
AGB	Aboveground biomass
ANOVA	Analysis of variance
BA	Basal area
DAFO	District Agriculture and Forestry Office
DBH	Diameter at breast height
df	Degrees of freedom
FAO	The Food and Agriculture Organization
GLA	Gap Light Analyzer
ha	Hectares
IUCN	The International Union for Conservation of Nature
LAI	Leaf area index
m.a.s.l	Metres above sea level
NMDS	Non-metric multidimensional scaling
NTFPs	Non-timber forest products
PAFO	Provincial Agriculture and Forestry Office
r	Pearson's correlation coefficient
R <sup>2</sup>	R-squared
REDD	Reducing Emissions from Deforestation and Forest Degradation
SD	Standard deviation
t	T-value

# 1. INTRODUCTION

## 1.1 Background

### *1.1.1 Current status and threats to biodiversity in Laos*

Tropical forests are remarkably abundant and rich in biological diversity. They are known to contain more than half of the terrestrial biodiversity on Earth (Lewis et al. 2015). However, tropical forests have been facing extensive destruction, especially over the past few decades, leaving only less than half of the world's tropical forests still standing (Brancalion et al. 2019; Malhi et al. 2014). Deforestation and forest degradation, among other reasons, have left many tropical forest species to become threatened or extinct (Tittensor et al. 2014). Degradation and loss of tropical forests impact far beyond the loss of species, also affecting climate regulation (Lawrence and Vandecar 2015) and the human well-being of approximately 1.5 billion people (Lewis et al. 2015).

Deforestation has received more public attention than forest degradation, although it is estimated that forest degradation is as widespread of a problem, if not greater (Hosonuma et al. 2012; Houghton 2005). Forest degradation, compared to deforestation, is challenging to quantify (Brewer et al. 2020; Tejaswi 2007), and there is still little consensus on what exactly forest degradation means, which makes identifying it even more challenging (Schoene et al. 2007; Simula 2009). FAO (2000) defines forest degradation as “changes within the forest which negatively affect the structure or function of the stand or site, and thereby lower the capacity to supply products and/or services”. The estimate for annual forest degradation is approximately 100 million hectares worldwide (FAO 2006). Undisturbed primary forests are becoming rarer, and according to FAO (2006), 60 per cent of the world's remaining tropical forests are either degraded or secondary forests.

Laos is a part of the Indo-Burma biodiversity hotspot (Myers et al. 2000), and the biodiversity in Laos has been recognised as one of the richest in the Himalayan, Indo-

Malayan, and Chinese regions (Myers 1992). In Laos, there are an estimated 8,000 to 11,000 species of flowering plants, many of which are still not identified or remain unknown (KNA and NAFRI 2016). However, botanical documentation in the country is severely lacking compared to neighbouring countries, and very few studies on plant taxonomy have been properly conducted since 1975 (STEa and UNDP 2004). Conversely, the documentation and monitoring of Lao fauna are relatively robust. In Laos, there are 166 reported species of reptiles and amphibians, over 700 species of birds, more than 90 known species of bats, 247 species of other mammals, of which over 100 species are large animals, and about 500 species of fish (STEa and UNDP 2004; WREA 2008). Moreover, new fauna species are still being discovered.

Like many other tropical countries, Laos has also been experiencing severe loss of forest cover. According to FAO's Global Forest Resources Assessment 2020 (FAO 2020), the forest cover in Laos decreased by approximately 7 per cent from 1990 to 2020. In 1990, the forests covered 17.843 million hectares in Laos, which reduced to 16.596 million hectares by 2020. During the same period, naturally regenerated forests saw a decline of about 9 per cent, with planted forests expanding by 10 per cent (FAO 2020). Although forests still cover about 70 per cent of Laos (FAO 2020), a significant portion of it is estimated to be degraded, with only a small fraction classified as primary forest (Lucas et al. 2013). This environmental degradation has led to severe consequences: a large number of flora and fauna species have become threatened or even extinct due to the ongoing deforestation and forest degradation (Thapa 1998). According to the International Union for Conservation of Nature (IUCN 2017), there are 420 species in Laos categorised on the Red List, of which five species are critically endangered, 23 species are endangered, and 25 species are vulnerable. Unfortunately, the conservation status of several species remains unclassified.

In Laos, several socio-economic and physical factors contribute to deforestation and forest degradation, serving as significant drivers of biodiversity loss. Shifting cultivation is acknowledged as one of the primary reasons for deforestation and the degradation of forests and land in Laos (Phompila et al. 2017). During the 1990s, about 6.5 million hectares of forest in Laos were estimated to be converted to shifting cultivation land

(Messerli et al. 2009; Sovu et al. 2009). Other direct drivers of deforestation and forest degradation in Laos are agricultural expansion, illegal logging, forest fires, fuel wood consumption and rubber cultivation. Some indirect drivers include population growth, lack of alternative sources of income, migration, large-scale concessions, market integration, and inappropriate governance and law enforcement (Chanthirath 1998; JICA 2014; Lucas et al. 2013; Rigg 2006).

### ***1.1.2 Importance of biodiversity***

Biodiversity provides several ecosystem services that all life on Earth depends on, such as climate regulation, soil formation and retention, nutrient and water cycling, biomass production, and pollination, which inherently affect human life quality, safety, and well-being (Díaz et al. 2006; IPBES 2019). Forests provide essential ecosystem services which directly contribute to human health, well-being, and quality of life (Haines-Young and Potschin 2010). The link between biodiversity and human health and well-being has been well-established (Sandifer et al. 2015). However, the detrimental impacts of deforestation and forest degradation extend beyond the compromise of these critical ecosystem services that underpin safety, stability, and well-being. These processes also pose a significant threat to local communities' access to non-timber forest products, which serve as vital reservoirs of village sustenance and wealth and as buffers during periods of crisis (Rigg 2006).

Non-timber forest products (NTFPs) play a crucial role in many people's lives in Laos, serving both as a means of subsistence and a source of income (Foppes and Kethpanh 1997). Studies have shown that in some instances, NTFPs contribute to over half of the food consumed and cash income generated by local communities in Laos (Clendon 2001; Foppes and Kethpanh 2000, 2004). Moreover, dependency on NTFPs has been linked to wealth. Foppes and Kethpanh (1997) found that low-income households depended on NTFPs almost totally, and up to 90 per cent of their income came from NTFPs, while the wealthiest households got only a small proportion of their income from NTFPs.

Furthermore, Foppes and Ketphanh (2004) found that in Laos, a total of 238 different edible plants, including fruits, seeds, leaves, shoots, tubers, roots, mushrooms and flowers, and 470 different animals, including fish, birds, mammals, reptiles, amphibians, molluscs and insects are consumed. Notably, wild meat and fish are significant sources of animal protein, particularly in rural areas where about 80 per cent of the Lao population resides (WFP 2007). Consequently, the availability of wildlife and access to it are vital for the nutrition and survival of many rural communities. Overall, in many Laotian communities, NTFPs play a crucial role in enhancing nutrition, especially among rural populations where access to markets is restricted (Foppes and Ketphanh 2004).

In addition to their role as food sources, forests provide various other products essential for daily life. These non-edible NTFPs include traditional medicines, as well as materials for house construction and handicraft production from bamboo, rattan, pandanus (*Pandanus fibrosus*), broom grass (*Thysanolaena maxima*) and paper mulberry (*Broussonetia papyrifera*) (Vongkhamsao 2007). In Laos, access to forests for NTFPs is not only essential for meeting basic needs but also contributes to broader aspects of human well-being and economic security (Foppes and Kethpanh 1997). By enabling rural communities to harvest and utilise NTFPs sustainably, forests serve as a critical resource for enhancing food security and alleviating poverty (Ironside 2017). Moreover, the sustainable management of NTFPs offers alternative livelihood opportunities, reducing dependency on single income sources and promoting resilience in the face of economic uncertainties (Rigg 2006).

## **1.2 Forest categories in Laos**

In Laos, forests are divided into three distinct categories: conservation, protection, and production forests. These classifications encompass various forest types, including dense forests, naturally sparse dry dipterocarp forests, regenerated forests, and degraded forests. Both conservation and protection forests comprise national, provincial, district and village forests and are regulated at many levels. The conversion of forests from one type to another is a controlled process, requiring approval from the Ministry of Agriculture

and Forestry in collaboration with relevant ministries, organisations, and local authorities (MAF 2021).

The Law on Forestry in Laos, established by the Department of Forestry under the Ministry of Agriculture and Forestry, defines conservation forests as areas devoted to preserving nature. These areas serve as crucial habitats for safeguarding plant, aquatic, and wildlife species while protecting forest ecosystems and conserving various natural, historical, cultural, touristic, environmental, and educational values. Conservation forests are esteemed for their rich biodiversity and scenic beauty, often designated as national or regional parks or even world heritage sites, with controlled access to ensure their preservation.

On the other hand, protection forests are defined to safeguard water sources and quality, mitigate soil erosion, enhance soil quality, and serve as critical buffers against natural disasters. In addition to preserving the regulatory and supportive functions of the ecosystem, protection forests are also meant to protect strategic areas for national defence.

In contrast, production forests are defined as forests designated to meet human needs and demands. These forests can be natural or planted, and they are managed to maintain a supply of wood and NTFPs, benefiting local communities and supporting their livelihoods. Production forest management aims to provide sustainable commodities that contribute to national socio-economic development and the eradication of poverty.

### ***1.2.1 Regulatory framework for forest categories***

Each forest type has its regulatory framework, characterised by objectives associated with each category. In Laos, the conservation forests are the most regulated, with even limited access to the site. Hunting, timber extraction, and collection of fuelwood or other NTFPs in conservation forests are prohibited by law. In protection forests, local people are permitted to collect NTFPs and fuelwood for subsistence use. However, timber extraction and hunting in protection forests are prohibited as it is in the conservation forests. On the

contrary, in production forests, local people are allowed to extract timber and other wood less than 60 cm in diameter at breast height (DBH). Also, the collection of NTFPs and hunting are permitted in production forests. However, for timber above 60 cm in DBH, a permission from the local committee is required in addition to getting a permission from the local forest officers at the District Agriculture and Forestry Office (DAFO).

While these regulations provide the fundamental guidelines for forest management, the regulatory framework is further nuanced by incorporating three distinct zones outlined in Lao forest law. In Laos, conservation and protection forests are characterised by a diverse regulatory framework based on different zones, each governed by specific management regulations. These zones, situated within or adjacent to conservation and production forests, are totally protected, controlled use, and buffer zones (MAF 2021).

The totally protected zones, located within conservation or production forests, are designated areas where no activities are permitted except for scientific research or recreational walking for ecotourism purposes. These zones are characterised by the highest conservation priority, with local people having minimal rights to access or utilise resources.

Controlled use zones can also be situated within or adjacent to conservation and protection forests. These zones allow for various activities aimed at sustainable resource utilisation. In addition to ecotourism, controlled use zones support harvesting NTFPs, agricultural production, and afforestation efforts. Furthermore, the controlled use zones are allocated to support family income generation, but on the condition that the felling of naturally grown trees for commercial purposes is prohibited.

On the other hand, buffer zones can be unforested or forested, and they can be part of the conservation or protection of forestland or situated nearby. Local villages are designated to manage buffer zones to prevent encroachment into conservation or protection forests.

The primary objective of buffer zones is to mitigate adverse impacts on forest ecosystems within conservation and protection forest areas.

In contrast to conservation and protection forests, production forests are not divided into different zones, and the same rules apply to all parts of the production forests. Violating the forest law can result in penalties, including fines and imprisonment, which vary depending on whether individuals are first-time or repeat offenders and the type and severity of the harm caused. These unpermitted activities include illegal forest conversion to other land uses, illegal wildlife hunting, being caught carrying firearms or other hunting equipment in the forest, and unauthorised tree felling in prohibited areas. Local communities are entrusted with the management of production forests, in addition, they collaborate with DAFO to monitor the conservation and protection forests.

### **1.3 Research problems and knowledge gaps**

Even if some studies based on floristic diversity (Lucas et al. 2013; Park et al. 2018; Yirdaw et al. 2019) have been conducted in Laos over the last few years, there is still a limited understanding of biodiversity dynamics in Lao forests. There is especially a gap in understanding how woody species diversity, composition, and structure vary across the three forest categories: conservation, protection, and production forests. The absence of comparative studies between the forest categories leaves the current knowledge on the subject scarce.

Human behaviour plays a crucial role in determining the effectiveness and success of conservation efforts (Reddy et al. 2017). Moreover, the attitudes, values, and behaviours of local communities have been closely associated with the success of conservation initiatives (Bennett 2016; De Snoo et al. 2013; Dietz et al. 2005; Ihemezie et al. 2021; Reddy et al. 2017). Hence, understanding the social context and cultural dynamics is pivotal for the long-term success of conservation outcomes (Bennett 2016; Kothari et al. 2013; Sandbrook et al. 2013). Even though the importance of considering social aspects in conservation is acknowledged, a significant proportion of studies in conservation often

overlook or inadequately integrate social science insights into their research methodologies and analyses (Bennett et al. 2017; Waylen et al. 2010). This gap in understanding the social context within conservation studies not only constrains the potential for long-term positive conservation outcomes but also diminishes the capacity to create meaningful value for local communities, ultimately jeopardising the efficacy of conservation efforts.

While some studies have assessed the public's legal awareness of forest laws (Gençay and Mercimek 2019; Macura et al. 2011; Sobeng et al. 2018), research examining the potential disconnect between local practices and regulatory frameworks in forest conservation remains scarce. However, understanding this gap is crucial as it is intricately linked to people's behaviours and attitudes towards conservation efforts (Gençay and Mercimek 2019; Macura et al. 2011). Particularly in Laos, a knowledge gap persists regarding the level of legal awareness of forest laws among local communities and whether there is a disparity between the regulatory framework established by forest officers and the actual practices and perceptions of local villagers. Understanding this gap is essential for ensuring that conservation policies are implemented effectively and accepted by the local communities.

Furthermore, there is a lack of long-term studies and published historical records examining the changes in forest conditions and their impacts on local communities in Laos, especially in the Luang Prabang Province. However, long-term data is crucial for assessing the sustainability of conservation measures and adapting management strategies to changing socio-economic and environmental conditions.

#### **1.4 Objectives of the study**

This research is part of my master's programme at the University of Helsinki. It was conducted in the Luang Prabang province of northern Laos in collaboration with the Souphanouvong University and the National University of Laos. The research is divided

into three segments: a forest inventory, interviews with local people, and an interview with a local forest officer.

The primary objective of the forest inventory was to conduct a comparative analysis of floristic species diversity and forest structure between the three different forest categories: in conservation, protection, and production forest sites. The interviews were conducted to understand how socioeconomic and other social factors influence the forests and conservation efforts. Through the interviews with local people, the aim was to gain insights into the historical context of the research areas, recent changes in forest conditions, local access rights, forest product utilisation, awareness and perceptions of biodiversity conservation, and impacts of ecotourism. Furthermore, the interview with a local forest officer aimed to provide a deeper understanding of the forest landscape and regulatory framework in Laos while also exploring the alignment and divergence between the perspectives of local forest officers and villagers.

## **1.5 Research questions and hypotheses**

Question 1: Is there a structural difference between the conservation, protection, and production forest sites?

Hypothesis 1: The conservation and protection forests are expected to exhibit similar structural characteristics due to their comparable management objectives and regulations. These characteristics are anticipated to be distinct from those observed in the production forest.

Question 2: How do species richness and evenness vary across the conservation, protection, and production forest sites?

Hypothesis 2: Species richness and evenness are expected to be highest in the conservation and protection forests compared to the production forest. This expectation is attributed to the lower levels of human disturbance and stricter management regulations in conservation and protection forests, which limit human access to forest resources.

Question 3: What are the differences in species composition and occurrence of rare species among the conservation, protection, and production forest sites?

Hypothesis 3: The species composition in the conservation and protection forests is expected to differ significantly from that in the production forest, reflecting distinct management objectives and ecological conditions of each forest type. Additionally, the conservation and protection forests are expected to exhibit a higher occurrence of rare species compared to the production forest due to their primary focus on biodiversity conservation and environmental protection.

Question 4: How does the forest officer's comprehension of the Lao forest law correspond with the understanding and perspectives of forest management regulations among the local communities?

Hypothesis 4: Some differences in awareness of forest regulations between local communities and a forest officer are expected, likely caused by the local people's lack of legal awareness and differences in interpretation of the forest law.

Question 5: What are the perceived benefits and drawbacks of living in close proximity to the conservation and protection forests, as reported by local villagers?

Hypothesis 5: Local villagers are expected to perceive benefits such as access to forest resources and ecosystem services but also drawbacks such as restrictions on land use.

Question 6: Are there differences between the villages regarding the utilisation of forest products and their perceptions of forest conservation?

Hypothesis 6: Variances in forest product utilisation and perceptions of forest conservation between the villages are expected to be observable, likely attributed to the socio-economic differences between the villages.

## 2. MATERIALS AND METHODS

### 2.1 Study sites

The study was conducted in northern Laos, in the province of Luang Prabang. Lao People's Democratic Republic (Lao PDR), or Laos, is a landlocked country in Southeast Asia with a size of 236,800 km<sup>2</sup>, of which 80 per cent is mountainous. The climate in the southern lowlands is classified as tropical, whereas the mountainous and northern parts of the country are classified as sub-tropical. Laos has two different seasons: the wet season from May to September and the dry season from October to April (Phongoudome and Sirivong 2007). The average annual rainfall varies across the country, from approximately 1,300 in the North to 3,000 millimetres in the South. In the northern and eastern mountainous areas, the mean annual temperature hovers around 20°C, while in the southern regions, the mean annual temperatures range from 25 to 27°C (Lao PDR 2013).

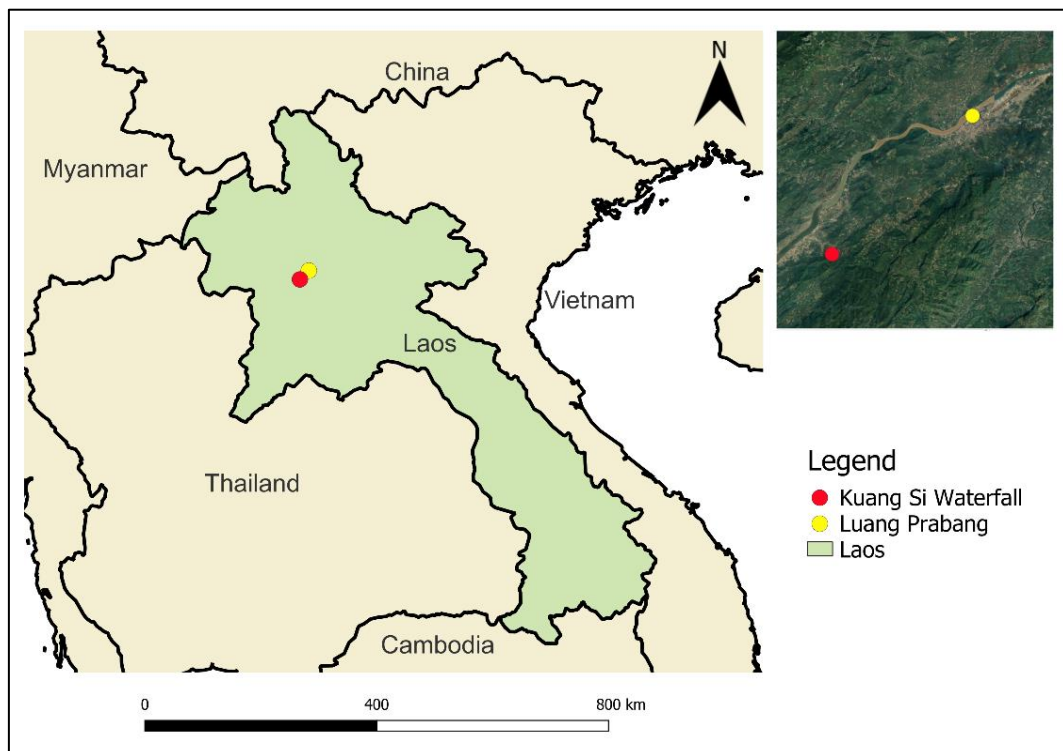


Figure 1. Location of Laos, the city of Luang Prabang and the Kuang Si Waterfall.

The forest inventory was carried out between January and February 2023 in three different sites: conservation ( $19^{\circ}44'41'' - 19^{\circ}44'48''\text{N}$  and  $101^{\circ}59'35'' - 101^{\circ}59'43''\text{E}$ ), protection ( $19^{\circ}44'26'' - 19^{\circ}44'34''\text{N}$  and  $101^{\circ}59'58'' - 102^{\circ}00'06''\text{E}$ ), and production ( $19^{\circ}45'07'' - 19^{\circ}45'26''\text{N}$  and  $101^{\circ}59'54'' - 102^{\circ}00'14''\text{E}$ ) forest sites. The study sites were within a one-kilometre radius of each other and next to the Kuang Si Waterfall, located approximately 20 kilometres southwest of the city of Luang Prabang. All three forest sites can be classified as upper mixed deciduous forests based on the FAO's classification (FAO 2010). The elevation of the conservation site ranges 560-600, the protection site ranges 590-640, and the production site ranges 410-500 m.a.s.l. The nearby city of Luang Prabang is located approximately 20 kilometres by air or 30 kilometres by road from the study sites (Fig. 1). The FAO's New LocClim software (Grieser et al. 2006) was utilised to provide estimates of average annual temperature and precipitation for the study site based on the coordinates. The estimated average annual temperature for the research area is  $24.4^{\circ}\text{C}$ , and the average annual precipitation is 1442 mm.

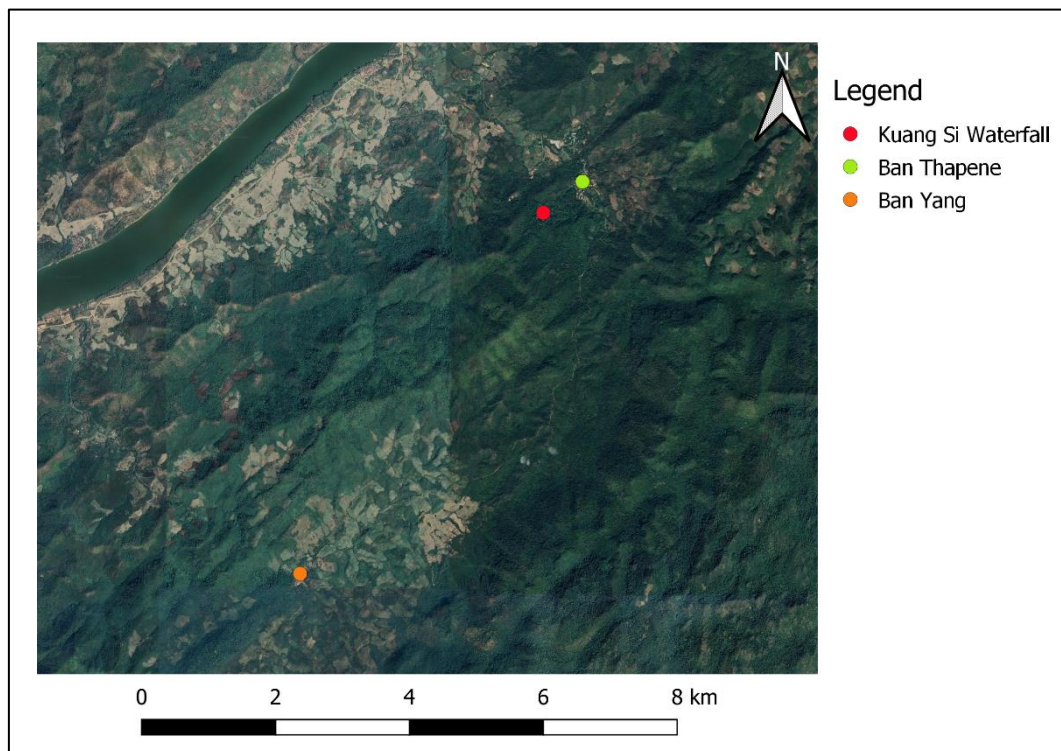


Figure 2. Map showing the locations of Ban Thapene and Ban Yang and their proximity to the Kuang Si Waterfall. The red dot marks the location of the Kuang Si Waterfall. The green dot marks the location of Ban Thapene, and the orange dot marks the location of Ban Yang.

The focus group discussions were conducted in March 2023 in two different villages: Ban Thapene (approximately 19°45'11"N and 101°59'50"E) and Ban Yang (approximately 19°42'03"N and 101°57'25"E). Ban Thapene serves as the gateway to the Kuang Si Waterfall, a famous tourist attraction in Luang Prabang Province, hosting an average of 230,000 visitors annually (Lau and Soukhy 2023). In contrast, Ban Yang, located approximately 7.2 kilometres southwest of Ban Thapene (Fig. 2), presents a more rustic and less developed environment. The forest inventory sites, comprising the conservation, protection, and production forests, are positioned around Ban Thapene and the Kuang Si Waterfall. Additionally, a forest officer from the DAFO in Luang Prabang was interviewed in March 2023.

## **2.2 Forest inventory design**

The forest inventory was carried out by using systematic plot sampling. The inventory data was initially documented on field data forms (Appendix 1) and subsequently entered into an Excel spreadsheet. The initial plot in all sites was selected randomly, but at least within 20 metres towards the interior forest from the forest edge to avoid the edge effects.

After the initial plot, measurements continued systematically, with plots placed 50 metres apart from one another. Sampling was conducted uniformly across all three sites, with 20 circular plots placed at each site. Each plot had a radius of 7.98 m, constituting an area of 200 m<sup>2</sup> (Fig. 3). In each site, an area of 0.4 hectares was sampled. In the whole study, 60 plots were placed and a total area of 1.2 hectares was sampled. Plot coordinates were recorded with a GPS device from the centre of each plot. Additionally, site physical characteristics such as altitude and slope were recorded in each sampling plot.

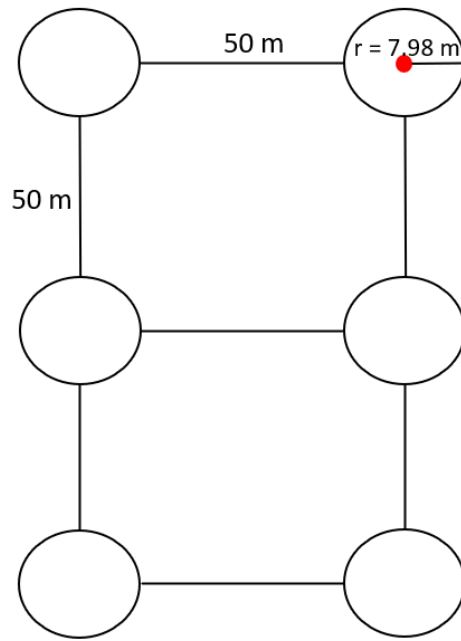


Figure 3. A total of 60 circular plots, each with a radius of 7.98 metres, were placed in three different sites, with 20 plots per site. The plot placement was carried out with a systematic approach and each plot was situated at 50-metre intervals. The first plot in each site was placed at a minimum distance of 20 metres from the edge of the site towards the interior forest.

Occasionally, the centre of a sample plot had to be relocated by 1-3 metres from its original position. In the conservation and protection sites, this was done to avoid the sample plot being placed on a forest path on which species did not grow and would, therefore, alter the abundance and diversity results of a plot. Additionally, it was necessary to avoid the nearby stream leading to the Kuang Si Waterfall at the conservation site. Therefore, occasionally, the location of a sample plot near the stream had to be slightly adjusted. Furthermore, the sampling in the production site had to be conducted in multiple smaller production forest stands to avoid burned areas since much of the production forest had been recently burned. In the end, the 20 plots in the production site were placed in four different production forest patches to conduct the sampling (Fig. 4). In summary, the decision to adjust the centre of sampling plots was guided by the need to maintain data integrity, minimise biases, and accommodate environmental constraints.

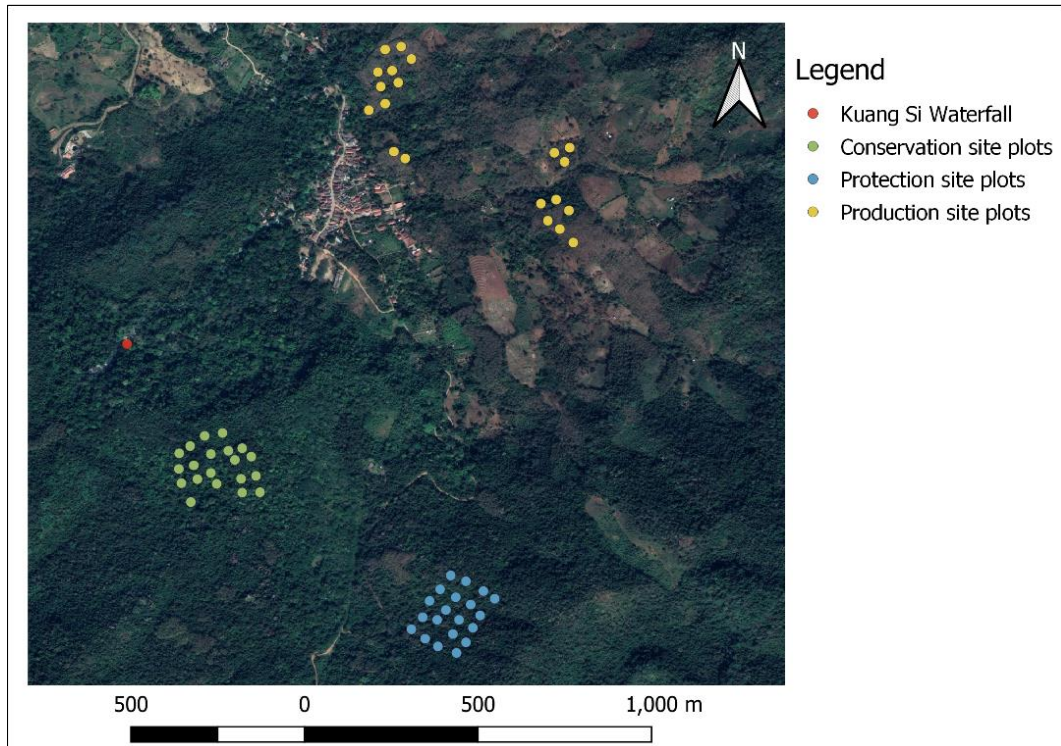


Figure 4. A map of the locations of the sampling plots based on the coordinates recorded at the centre of each plot across the three different sites located around Ban Thapene and next to the Kuang Si Waterfall. The green dots show the locations of the plots in the conservation site, the blue dots are the protection site's plots, and the yellow dots mark the plots in the production forest sites. The red dot marks the location of the Kuang Si Waterfall.

### *2.2.1 Forest structure*

In each sampling plot, measurements of DBH were taken of all mature living trees and stems of multi-stemmed trees with  $DBH > 5$  cm. DBH was measured at 1.3 m height by using a talmeter. Trees with  $DBH < 5$  cm were not measured, however, these trees were still identified and counted, like all other individual woody species that are taller than 5 cm. The measurements of diameter at breast height were used for aboveground biomass and basal area estimation. With multi-stemmed trees, DBH was calculated by taking the square root of the sum of the squared DBHs of all tree stems.

Additionally, canopy openness was estimated by capturing hemispherical photographs using a Sigma 8 mm fish-eye lens mounted on a Canon EOS 700D camera. Three digital photographs of the canopy were taken in each sampling plot.

### ***2.2.2 Woody species and dominant climbers***

This study divided woody species into four groups according to their size. These size classes were seedlings ( $0.05 < \text{height} < 1.3 \text{ m}$ ), saplings ( $\text{height} \geq 1.3 \text{ m}$  and  $\text{DBH} < 5 \text{ cm}$ ), and mature trees ( $\text{DBH} \geq 5 \text{ cm}$ ), all of which were identified and counted, and germinants ( $\text{height} < 0.05 \text{ m}$ ) which were excluded from the survey. The germinants were excluded from the study because of their high mortality and difficulty identifying them. However, dominant climbers were identified and included in the survey. This study defines dominant climbers as the most abundant climbers on each plot, with a minimum abundance of three individuals per plot. Additionally, rare woody species were identified in all three study sites. In this research, rare species are defined as those consisting of only a single individual per study site, often referred to as singletons (Magurran 2021).

### ***2.2.3 Herbaceous species***

The dominant herbaceous species were identified, and their ground cover percentage was estimated. Herbaceous plant sampling was carried out by randomly placing four one-square-metre quadrats within each circular sampling plot. The herbaceous species' ground cover percentages were estimated within the quadrats, and dominant herbaceous species were identified. To enhance the accuracy of ground cover percentage estimates, the one-square-metre quadrats were subdivided into four smaller square quadrants, and the estimation process was conducted individually for each quadrant. Subsequently, an average of the four quadrat estimations of herbaceous cover percentages was calculated to provide a mean herbaceous cover value for each plot. Additionally, a site-specific average was calculated using all the plot-based means within each site.

## **2.3 Interviews with the local people**

Interviews with the local people were conducted in two different villages, Ban Thapene and Ban Yang, both situated close to the forest inventory sites and the Kuang Si Waterfall. The interviews were conducted as focus group discussions involving eight to ten participants of different genders and ages. The same interview was conducted in both

villages, and it was divided into six sections, which were the historical context of the research area and recent changes in the forest conditions, local access rights, unpermitted activities within the forests, utilisation of the forests and forest products, awareness and perceptions of biodiversity conservation, and the impacts of ecotourism (Appendix 2).

The first section of the focus group discussion interviews was to determine the research areas' site history and recent changes in the forest conditions. The interview participants were asked about the observed changes in weather patterns and the availability of forest products. The second section aimed to assess the access rights of local people to the three distinct forest categories and their knowledge of Lao forest law. The third section aimed to evaluate the residents' understanding of the penalties associated with unpermitted activities in forests and their perception of the penalties, forest surveillance, and their effectiveness. The fourth section aimed to determine the utilisation purposes of the three forest sites. In this section, the participants were questioned about the collected forest products, such as fuelwood and other specific NTFPs, timber, etc., and whether these items are intended for subsistence use or generating income through sale. The fifth section aimed to understand the local awareness and perceptions of biodiversity conservation. This section included questions regarding forest education initiatives and views on conservation. The sixth and final section aimed to understand how the local people view tourism and the current and potential impacts of ecotourism on environmental and socio-economic factors.

The focus group discussions were audio-recorded with the participants' consent. Notes were diligently taken during the interviews, and the essential elements were translated in real-time. Subsequently, the interviews were translated by the interviewing research team at Souphanouvong University premises.

#### **2.4 Interview with the forest officer**

An interview with a DAFO officer from Luang Prabang was conducted at the premises of Souphanouvong University. The DAFO interview consisted of eight sections: policies

related to the three forest categories, monitoring, management, conservation planning, conservation projects, the effectiveness of forest conservation and protection, unpermitted activities, and education and awareness (Appendix 3). Like the focus group discussions, the DAFO interview was audio-recorded, with the officer's consent, and detailed notes were taken during the interview session. Essential elements of the interview were also translated in real-time, and subsequently, the interviewing research team translated the interview.

## **2.5 Ethical considerations of the interviews**

Participation in the focus group discussions and the DAFO interview was entirely voluntary. The interviewing team ensured that informed consent was obtained from all interviewees prior to conducting the interviews. This process included a thorough explanation of the study's purpose, the procedures involved, and the potential uses of the information gathered. Moreover, the confidentiality and anonymity of the participants were prioritised throughout the research. Additionally, participants were informed that they could withdraw from the interviews at any time without any repercussions.

Furthermore, this thesis will be sent to the local Lao forest authorities. The aim is that the insights gained from the study could contribute to local development efforts and inform policy decisions. By adhering to these ethical standards, the research maintains its integrity and respects the rights and well-being of all participants involved.

## **2.6 Data analysis**

The aboveground biomass of woody vegetation was estimated using a general equation originally developed for moist tropical forests by Brown (1997) which was subsequently modified Pearson et al. (2005).

$$Biomass = e^{[-2.289+2.649 \times \ln(DBH)-0.021 \times \ln(DBH)^2]} \quad (1),$$

where biomass is in kilograms and DBH in centimetres.

Using this equation, plot-based averages were determined by summing the biomass of all living trees within each plot. Site-specific calculations were then performed by summing the plot-level estimates for each site and dividing the result by 0.4, representing the total sampled area per site, to obtain biomass estimations per hectare.

To calculate canopy openness and leaf area index (LAI), the hemispherical photographs were installed into Gap Light Analyzer (GLA) software version 2.0 (Frazer et al. 1999). The mean of the three pictures on each plot was used to give a plot-based mean value for canopy openness and LAI. Later, these plot-based means were averaged to produce the mean canopy openness and LAI values for each site.

To measure woody species diversity in all three sites, species richness and abundance and the Shannon and Simpson diversity indices were used. Species evenness was determined by calculating the Shannon evenness for each site. Additionally, the Jaccard similarity coefficient and a non-metric multidimensional scaling (NMDS) ordination were used to evaluate the similarity in woody species composition among sites. Furthermore, two-way analysis variance (ANOVA) was used to identify variations in the mean values of species richness, evenness, and abundance across three sites. Subsequently, the Tukey multiple comparison test was used for statistically distinct means for further analysis. These calculations and analyses were performed using R version 4.3.2 (R Core Team 2023).

Furthermore, the maps of this study were created with QGIS 3.22 (QGIS Development Team 2021), and ChatGPT 3.5 (OpenAI 2023) and Grammarly (Grammarly Inc. 2024) were used as text editing tools to ensure readability.

### 3. RESULTS

#### 3.1 Forest inventory

##### 3.1.1 Forest structure

All three stands exhibited a decline from younger to mature size classes (Fig. 5). Notably, the protection forest stand displayed a gradual decrease across the three size classes, while the conservation and production sites showed a sharp and considerable reduction in abundance from saplings to mature trees. Furthermore, the protection forest exhibited the lowest abundance of woody individuals, having notably fewer individuals of seedlings and saplings than both the conservation and production forests. The tree size class distribution in all stands can be characterised by a reverse-J pattern. This characteristic distribution suggests a healthy regeneration of the woody species.

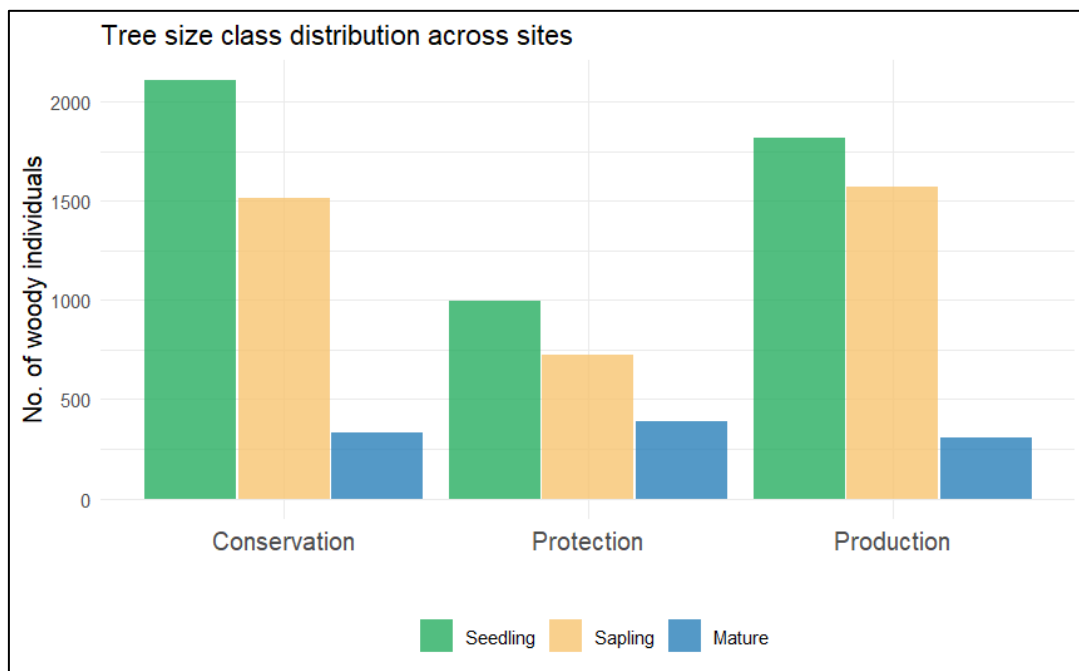


Figure 5. The distribution between tree size classes across the three study sites. Number of seedlings, saplings, and mature woody individuals per site.

The production site had the highest mean DBH, which was primarily governed by the presence of mature teak trees (*Tectona grandis*) cultivated for timber. In contrast, the protection site displayed the smallest mean DBH among the three sites (Table 1). On the other hand, the conservation forest demonstrated considerable variation in tree DBH, as indicated by the high standard deviation (SD).

The conservation site had the highest basal area (BA), with a mean of 21.2 m<sup>2</sup> ha<sup>-1</sup> and the highest SD across the sites. The protection and production sites displayed close similarities regarding mean basal areas and their standard deviations.

The mean canopy openness and its SD showed consistent values between the conservation and protection sites, with the conservation forest having slightly lower canopy openness than the protection forest. In contrast, the production forest exhibited significantly higher canopy openness than the other two sites. The high canopy openness observed in the production forest was primarily influenced by the absence of leaves on teak trees, which were the dominant woody species on the site. It is important to note that this elevated canopy openness represents a temporary condition significantly influenced by the seasonal absence of leaves and does not accurately reflect the year-round conditions of the production site.

The mean herbaceous cover percentage was high and relatively consistent between the protection and conservation forests, with the protection forest recording the highest herbaceous cover value and its SD. In contrast, the production forest had the lowest mean herbaceous cover and its smallest SD, suggesting a lower degree of variability within the site. The other two sites demonstrated higher variability in herbaceous cover, indicated by the higher SD.

The LAI in the production forest was significantly lower than in the other two sites. As with the canopy openness, this finding is also primarily attributed to the absence of leaves on teak trees, which dominated the site. Nevertheless, the production forest also exhibited

the highest SD of LAI. Plots within the production site that were not dominated by teak trees displayed LAI values comparable to those observed in the conservation and protection forests. The conservation and protection sites demonstrated relatively consistent LAI values regarding the mean and its SD.

Table 1. Summary of mean diameter at breast height, basal area, canopy openness, herbaceous cover, and leaf area index in the three different forest sites. The table presents mean values followed by standard deviations.

<b>Stand</b>	<b>Mean DBH (cm)</b>	<b>Mean BA (m<sup>2</sup> ha<sup>-1</sup>)</b>	<b>Mean canopy openness (%)</b>	<b>Mean herbaceous cover (%)</b>	<b>Mean LAI</b>
<b>Conservation</b>	14.3 ± 10.9	21.2 ± 13.6	19.8 ± 3.0	28.6 ± 14.6	2.11 ± 0.24
<b>Protection</b>	12.4 ± 8.7	17.2 ± 8.0	21.5 ± 4.3	29.3 ± 18.9	2.04 ± 0.28
<b>Production</b>	15.3 ± 7.7	17.5 ± 8.4	60.4 ± 16.2	21.1 ± 9.8	0.69 ± 0.53

Canopy openness correlated weakly ( $r = 0.3406$  and  $r = 0.2771$ , respectively) but positively with herbaceous species cover in the conservation and protection sites (Fig. 6, 7). This finding suggests that as canopy openness increased, herbaceous species cover also increased. This positive association aligns with the general expectation because higher canopy openness typically allows more sunlight to reach the forest floor, fostering herbaceous vegetation growth.

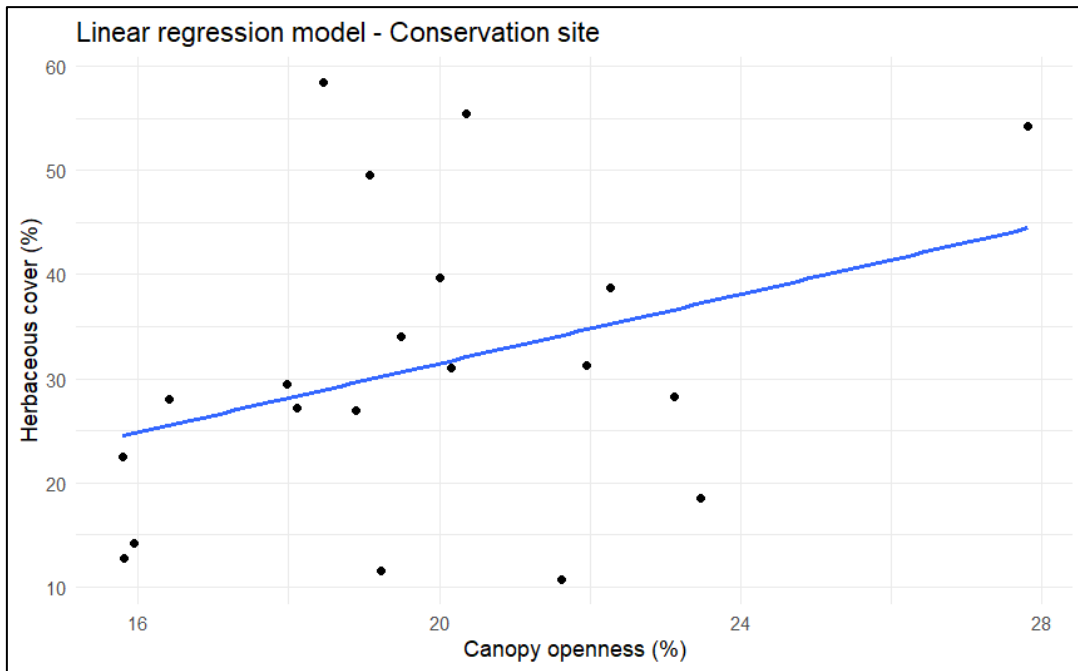


Figure 6. The linear regression model illustrates the positive correlation between canopy openness and herbaceous species cover at the conservation site ( $r = 0.3406$ ,  $t = 1.54$ ,  $df = 18$ , adjusted  $R^2 = 0.067$ ). The positive correlation suggests that as canopy openness increases, herbaceous species cover tends to increase as well. The blue line represents the best-fit linear relationship between the variables, with the dots representing actual measurements.

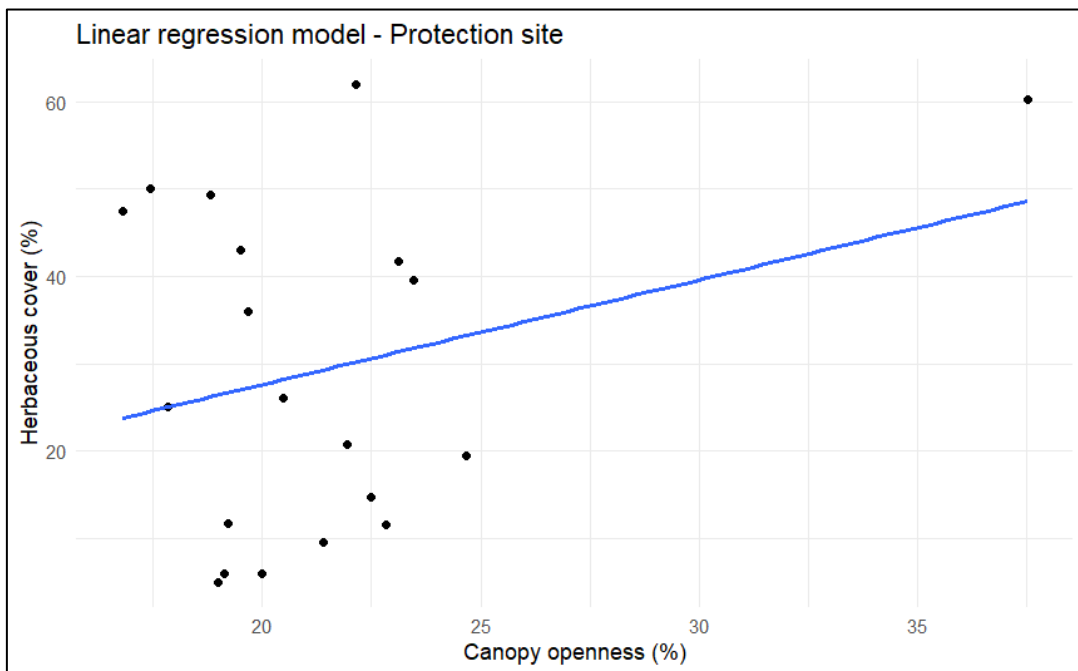


Figure 7. The linear regression model illustrates the positive correlation between canopy openness and herbaceous species cover at the protection site ( $r = 0.2771$ ,  $t = 1.22$ ,  $df = 18$ , adjusted  $R^2 = 0.025$ ).

Conversely, the production site exhibited a negative correlation between the canopy openness and herbaceous species cover (Fig. 8). This unexpected finding suggests that the site's herbaceous cover decreases as the canopy openness increases. The dominance of teak trees, which shed leaves during the dry season when the inventory measurements were conducted, is likely contributing to this negative correlation.

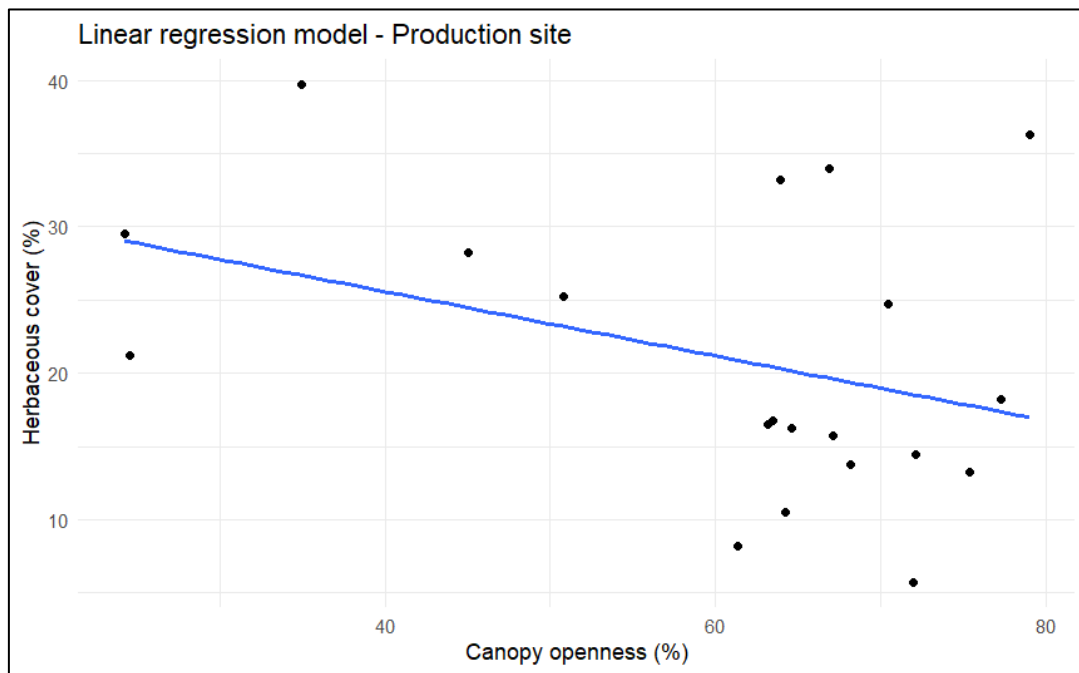


Figure 8. The linear regression model illustrates the negative correlation between canopy openness and herbaceous species cover at the production site ( $r = -0.3652$ ,  $t = -1.66$ ,  $df = 18$ , adjusted  $R^2 = 0.085$ ).

### 3.1.2 Aboveground biomass estimation

The aboveground biomass (AGB) was estimated to be the largest in the conservation site, with a value of  $197.9 \text{ Mg ha}^{-1}$  (Fig. 9). The estimated AGB for the protection and production sites were considerably lower, at  $144.7$  and  $137.1 \text{ Mg ha}^{-1}$ , respectively.

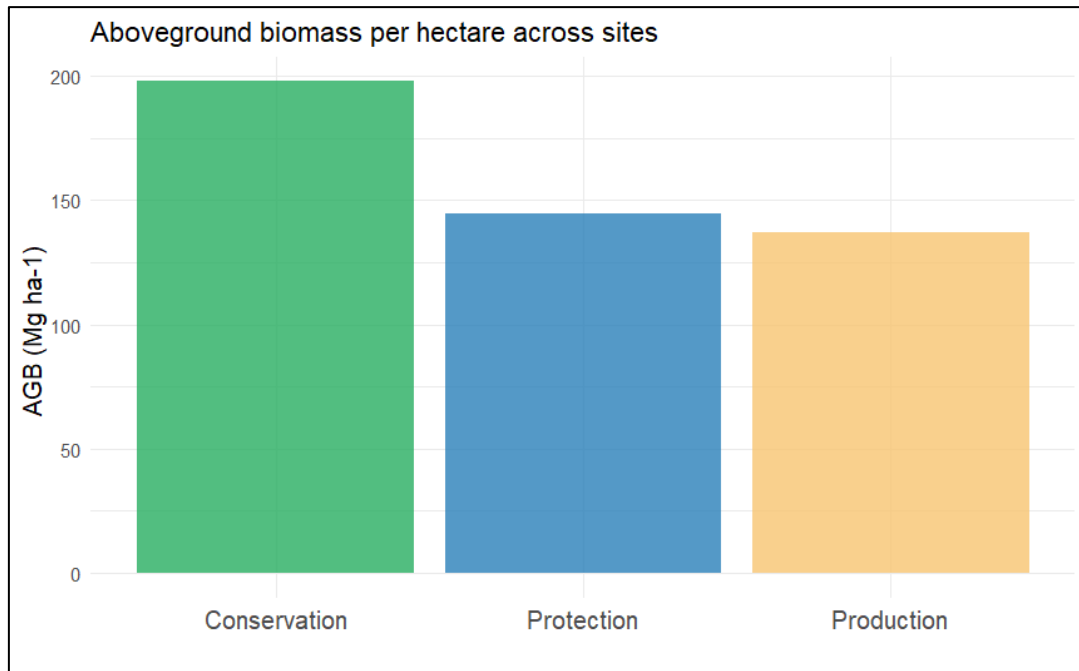


Figure 9. Estimation of aboveground biomass per hectare across three different sites.

### 3.1.3 Woody species richness

Among the three sites, the conservation site exhibited the highest woody species richness, with a total of 128 species, followed by the protection site with 124 species. In contrast, the production site had the lowest number of woody species, with a value of 89 (Table 2). Across all sites, the total number of woody species found in the study was 200.

Table 2. Total woody species richness per site and mean species richness per plot on the three sites. Mean values followed by standard deviations are presented in the table.

Stand	Woody species richness	Mean plot-based woody species richness
Conservation	128	20.7 <sup>a</sup> ± 3.57
Protection	124	23.6 <sup>b</sup> ± 2.14
Production	89	18.0 <sup>c</sup> ± 3.42

In the table, different letters (a, b, c) are used as superscripts to denote statistical significance among the three sites. The means sharing the same letter are not significantly different, while values without a common superscript differ at the 0.05 significance level ( $P < 0.05$ ).

When considering the 200 m<sup>2</sup> plots within each site, the protection site exhibited the highest mean plot-based woody species richness, accompanied by its lowest SD (Fig. 10). The conservation site had the second highest plot-based woody species richness, while the production site exhibited the lowest mean value of woody species per plot. Statistical analysis using ANOVA revealed significant differences in plot-based species richness among all sites. Notably, the comparison between the protection and production sites yielded the lowest p-value ( $p = 0.0000016$ ), indicating a highly significant difference. Additionally, the comparison between the protection and conservation sites resulted in a p-value of 0.014, which was smaller than the p-value observed between the conservation and production sites ( $p = 0.022$ ).

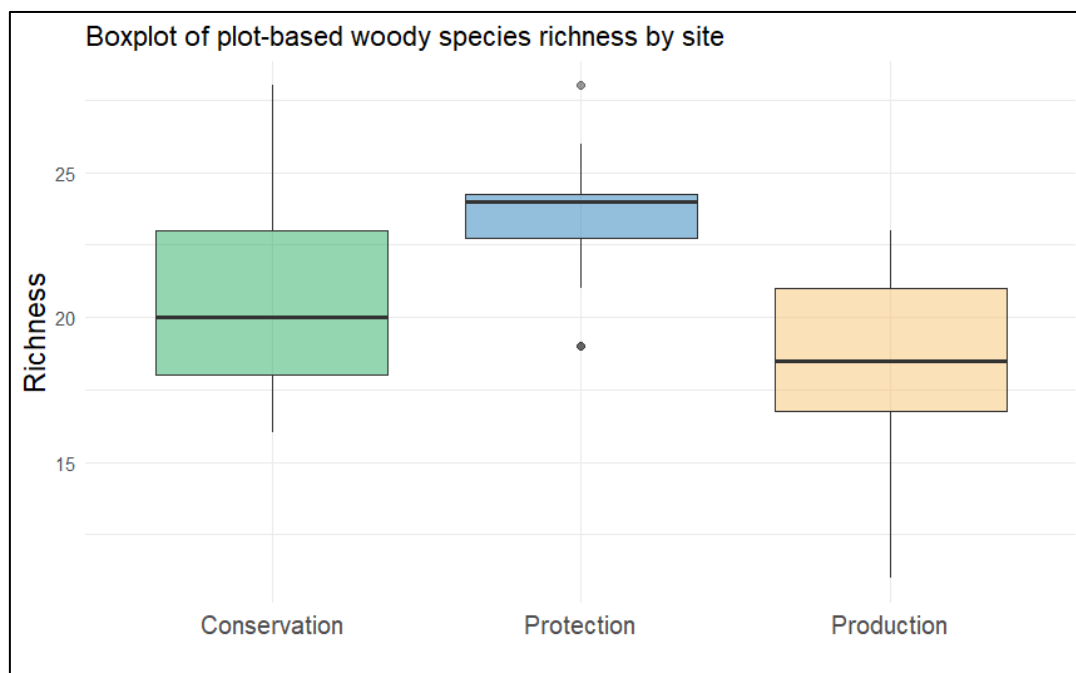


Figure 10. Boxplot of woody species richness per 200 m<sup>2</sup> plots in the different study sites. The bold line shows the median and the box shows the interquartile range. The whiskers show the maximum and minimum range of the data. The individual points are data outliers.

### 3.1.4 Woody species accumulation curves

The woody species accumulation curves (Fig. 11, 12, 13) represent the cumulative number of distinct woody species recorded as more plots were surveyed. The curves do not exhibit a significant levelling-off but continue to rise steadily. This suggests that additional sampling is needed, as it is highly likely that there are more species in each of

the study sites that were not captured in the sampling plots. The current sampling efforts appear insufficient to comprehensively capture all the woody species on each site.

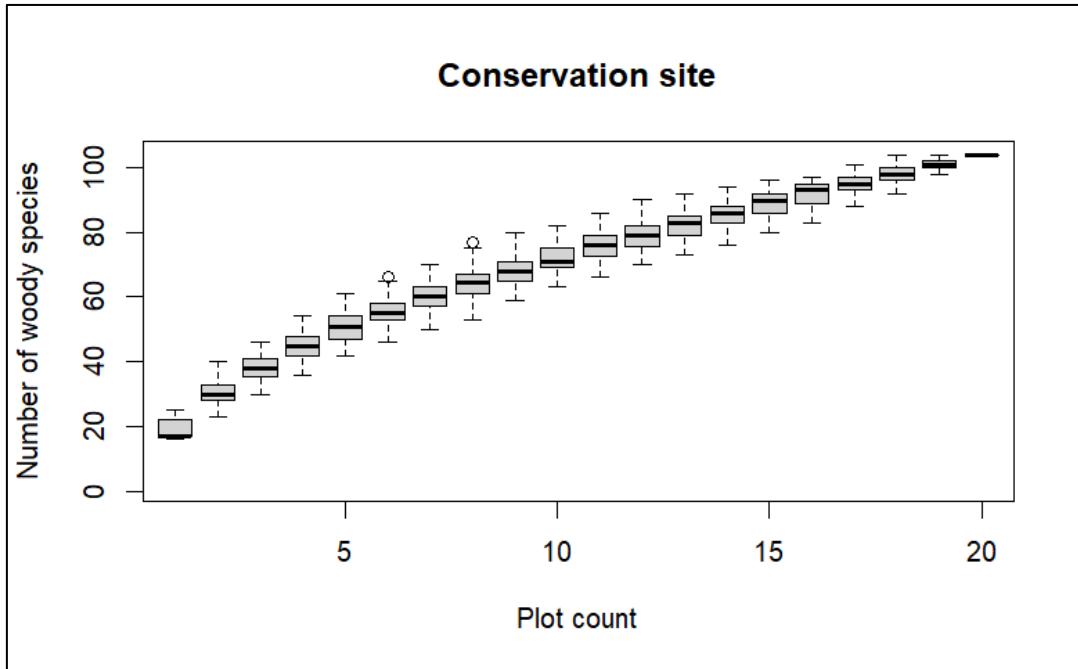


Figure 11. Woody species accumulation curve for the conservation site.

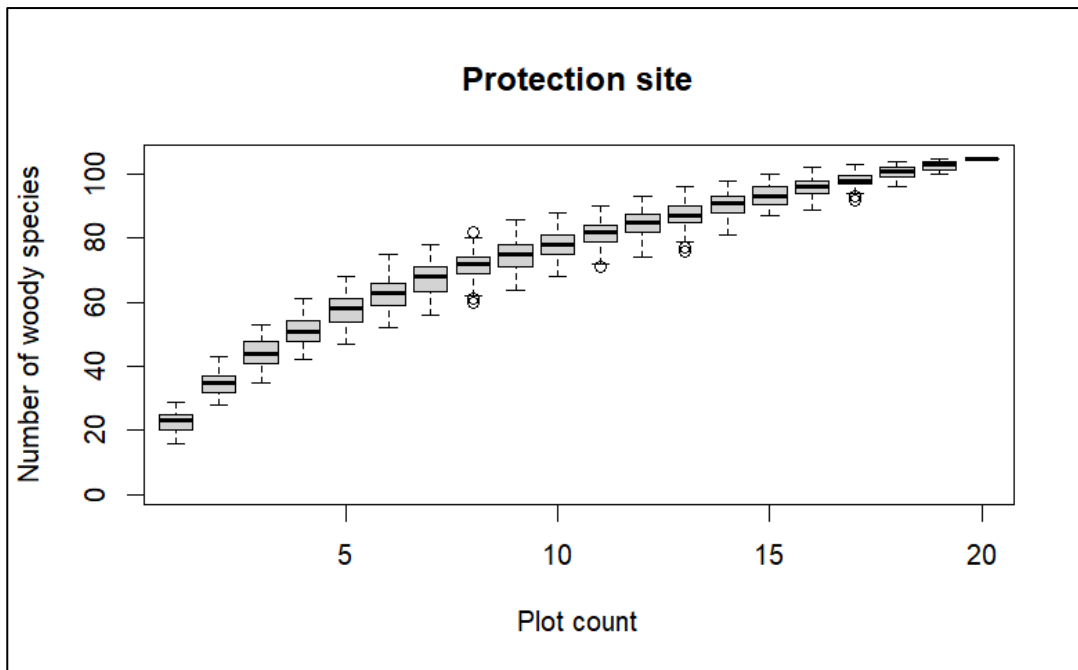


Figure 12. Woody species accumulation curve for the protection site.

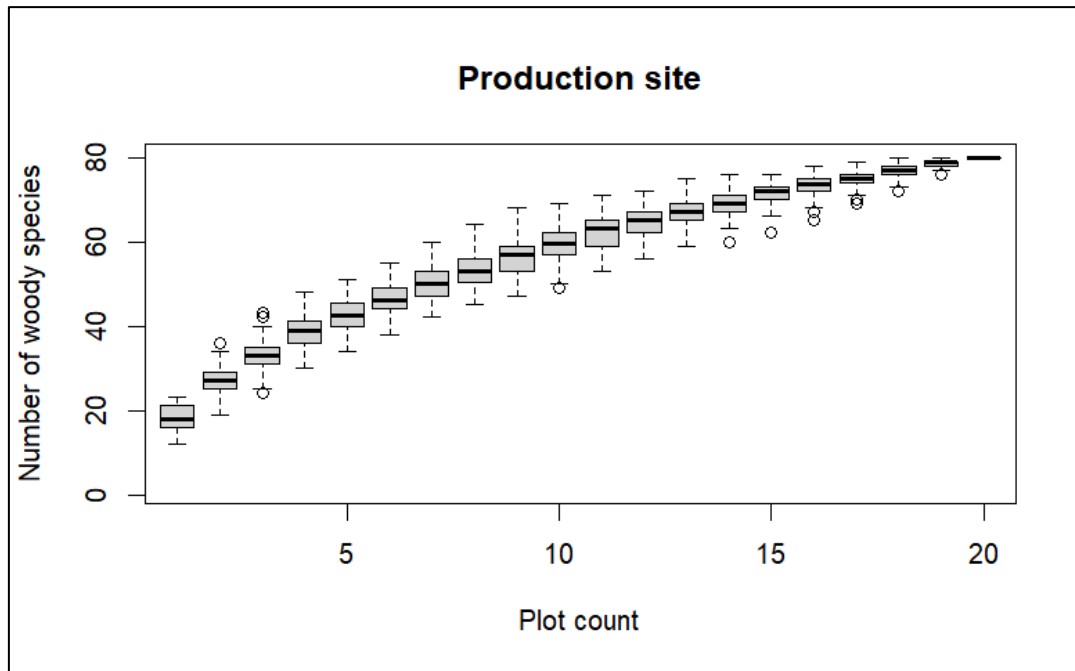


Figure 13. Woody species accumulation curve for the production site.

### 3.1.5 Dominant climber species

Dominant climber species richness was highest in the conservation site, with 22 species identified (Table 3). The protection site closely followed with 19 dominant climber species, while the production site exhibited the lowest climber diversity, with 8 different dominant species observed. Overall, a total of 36 dominant climber species were identified across all sites in this study. A similar trend to the site-specific dominant climber species richness was also observed in the mean count of dominant climber observations per plot. On average, the conservation site had 2.15 different dominant climber species observations per plot, followed by 1.85 species per plot in the protection site and 1.05 species per plot in the production site.

Table 3. Dominant climber species richness per site and the mean number of climber species observations per plot.

Stand	Climber species richness	Mean climber observations per plots
Conservation	22	2.15 <sup>a</sup> ± 1.33
Protection	19	1.85 <sup>a</sup> ± 1.30
Production	8	1.05 <sup>b</sup> ± 0.51

In the table, different letters (a, b) are used as superscripts that denote statistical significance among the three sites. The means sharing the same letter are not significantly different, while values without a common superscript differ at the 0.05 significance level ( $P < 0.05$ ).

### 3.1.6 Dominant herbaceous species

The conservation site had the highest number of dominant herbaceous species, with 37 species (Table 4). The protection site had the lowest number of dominant herbaceous species, with 22 different species. The production site exhibited the second-highest richness of dominant herbaceous species, totalling 36 species. Across all sites, the study found a total of 79 different dominant herbaceous species.

Table 4. Dominant herbaceous species richness per site.

Stand	Herbaceous species richness
Conservation	37
Protection	22
Production	36

### 3.1.7 Woody species evenness

The protection site demonstrated the highest species evenness, with a mean of 0.535. Conversely, the conservation site displayed the lowest evenness of 0.453, accompanied by the lowest SD. Nonetheless, this value was closely aligned with the evenness recorded at the production site, which was 0.457. The ANOVA model for species evenness revealed statistical significance in evenness values between the conservation and protection sites ( $p = 0.0000010$ ) and between the protection and production site ( $p = 0.0000029$ ).

However, the woody species evenness between the conservation and production sites was not statistically significant (Fig. 14).

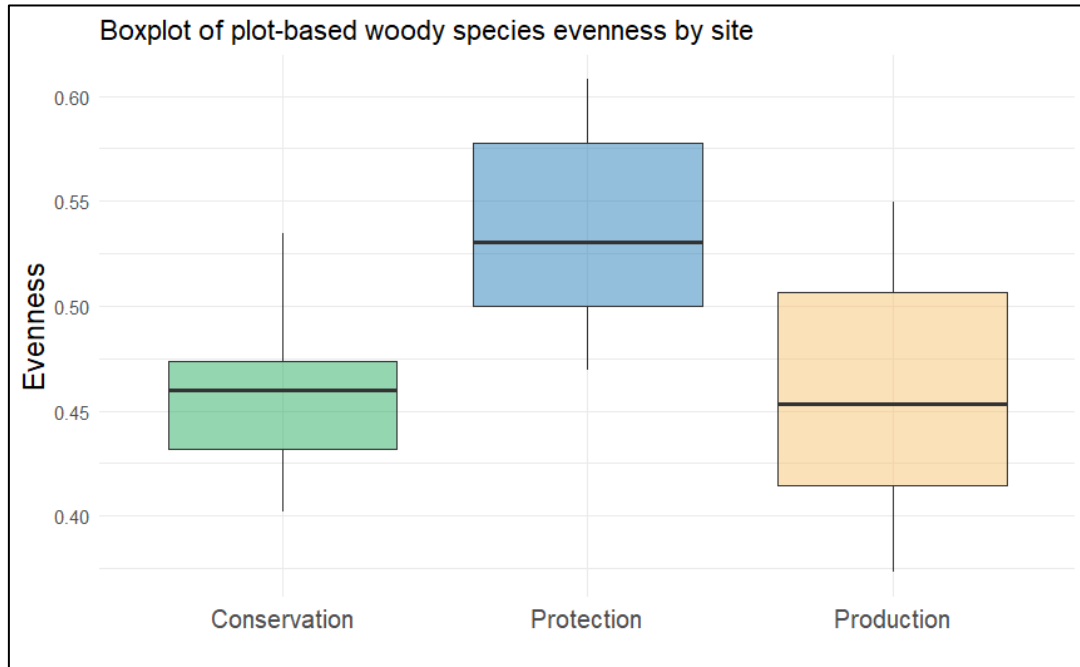


Figure 14. Boxplot of woody species evenness (Shannon) per 200 m<sup>2</sup> plots across different sites. The protection site exhibited the highest evenness with a mean value of 0.535, followed by the production site with the second-highest mean of 0.457. The conservation site recorded the lowest mean evenness at 0.453, accompanied by the smallest standard deviation. Interestingly, the evenness median value in the conservation site is slightly larger than that in the production site, contrasting with the mean values.

### ***3.1.8 Woody species abundance***

The total woody species abundance was highest in the conservation site and second highest in the production site (Table 5). Interestingly, the total woody species abundance was the lowest in the protection site, with almost only half as many woody individuals as in the conservation site. However, out of the three sites, the protection site had the highest number of mature trees, and the conservation site came second regarding the number of mature trees. The conservation site had the highest abundance of seedlings, and the production site had the highest abundance of saplings.

Table 5. Woody species abundance by size classes: seedlings, saplings and mature trees, and the total abundance of woody species on each site.

Stand	Seedlings	Saplings	Mature	Total abundance
Conservation	2106 <sup>a</sup>	1513 <sup>a</sup>	330 <sup>ab</sup>	3949
Protection	998 <sup>b</sup>	723 <sup>b</sup>	389 <sup>b</sup>	2110
Production	1818 <sup>a</sup>	1572 <sup>a</sup>	305 <sup>a</sup>	3695

In the table, different letters (a, b) are used as superscripts to denote statistical significance among the three sites. Values sharing the same letter are not significantly different, while values without a common superscript differ at the 0.05 significance level ( $P < 0.05$ ).

### 3.1.9 Diversity indices

The normalised Shannon diversity index was highest in the protection site, indicating the greatest overall diversity of woody species with an index value of 0.84 (Table 6). The conservation site also exhibited high biodiversity, with the second-highest Shannon index of 0.76. In contrast, the production site had a slightly lower Shannon index of 0.73, suggesting a somewhat lower overall diversity of woody species compared to the other sites.

The Simpson diversity index results show a similar trend to the Shannon diversity index. The protection site had the highest Simpson diversity index value of 0.95, indicating a notably high woody species diversity. The conservation site had the second-highest Simpson index of 0.92, and the production had a value of 0.90, which was the lowest compared to the other two sites.

The Shannon and Simpson diversity indices suggest that the conservation and protection sites exhibit a higher woody species diversity than the production site. Still, all sites seem to show a notably high level of woody species diversity.

Table 6. Shannon (normalised) and Simpson diversity indices per site.

Stand	Shannon diversity index (normalised)	Simpson diversity index
Conservation	0.76	0.92
Protection	0.84	0.95
Production	0.73	0.90

### 3.1.10 Rare species

The conservation site had the highest number of rare species, or singletons, consisting of only one individual. There were 32 singletons in the conservation site. The protection site had 22 different singletons, and the production site had 16.

### 3.1.11 Species composition and similarity

The conservation and protection sites had the highest number of shared species, with the Jaccard coefficient of similarity index being 0.72 (Table 7). The Jaccard coefficient between the protection and production sites was 0.50, indicating that half of the species found in one site were also present in the other, while the remaining half were exclusive to the other site. The lowest species' similarity was between the conservation and production sites, with the Jaccard coefficient being 0.45.

Table 7. Matrix of the Jaccard coefficient of similarity results between different sites.

Stand	Conservation	Protection	Production
Conservation	1		
Protection	0.72	1	
Production	0.45	0.5	1

The NMDS (Fig. 15) analysis reveals a significant overlap among the three sites, indicating a large degree of similarity in species composition across all sites. However, the dispersion of points also highlights distinct species unique to each site.

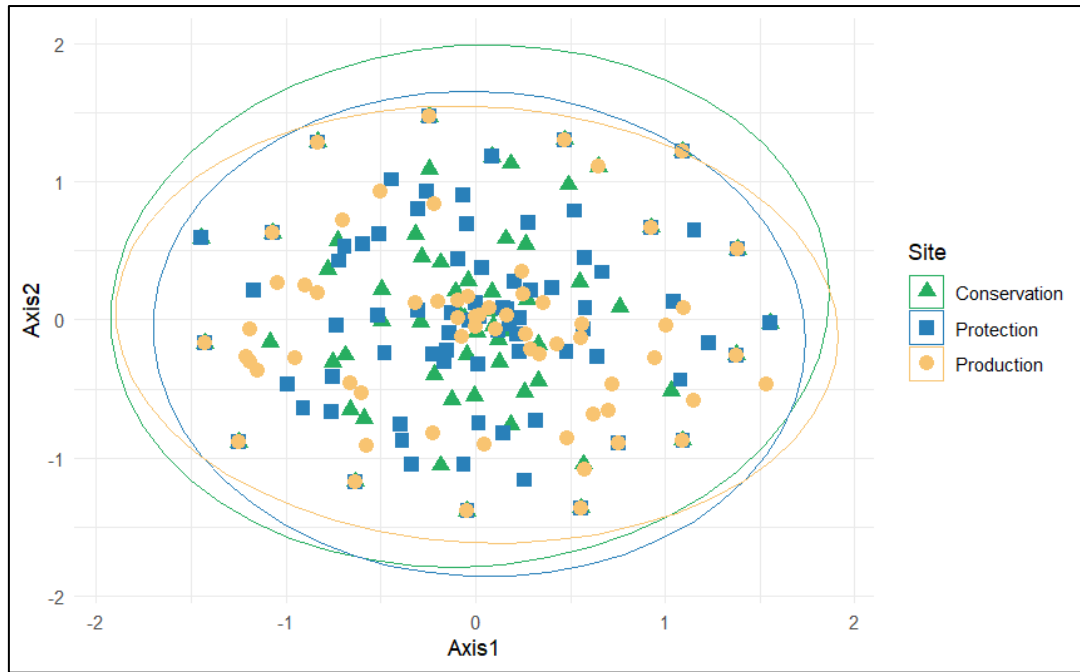


Figure 15. A NMDS ordination illustrating the dissimilarity of species composition between the sites. The green triangles represent the conservation site, the blue squares denote the protection site, and the yellow circles depict the production site. The Axis1 and Axis2 represent the maximum variation based on the rank order of dissimilarity and they do not have intrinsic meanings.

## 3.2 Focus group discussions

### 3.2.1 Site history and the recent changes

The interview participants from both villages had observed significant changes in weather patterns over the past decade, between 2013 and 2023. Their observations collectively pointed to a noticeable decrease in rainfall, accompanied by extended periods of drought, a clear rise in temperature, and the frequency of storms.

Additionally, the residents of Ban Thapene and Ban Yang acknowledged an increase in forest cover around the villages, which they attributed to local conservation initiatives. Furthermore, the expansion of forest cover was directly linked to a rise in the availability of NTFPs. Moreover, members from both communities reported an increase in the abundance of wild vegetables, bamboo shoots, and mushrooms, highlighting tangible benefits resulting from the conservation efforts that were previously conducted in the area.

The participants from Ban Thapene reported a rejuvenation of local wildlife, such as the return of junglefowl (*Gallus gallus*) and deer, which was linked to the increase in forest cover. Conversely, the residents of Ban Yang reported a declining trend in wildlife populations, including wild pigs, deer, and junglefowl, attributing this trend to overhunting.

The villagers from Ban Thapene reported that the forest around Kuang Si Waterfall has been under conservation since 1996 or 1997. Moreover, the residents of Ban Yang indicated that conservation efforts in the areas near Ban Yang commenced more recently, with initiatives initiated around 2012 and 2014. In the case of both villages, the land areas were said to be production forest and agricultural land before they were designated for conservation.

### ***3.2.2 Access rights and management***

The residents of Ban Thapene reported that all activities in conservation forests are prohibited. In contrast, the residents of Ban Yang noted that conservation forests can be accessed to collect NTFPs but not for any other activities. The views on access rights regarding the use of protection forests also differed between the two villages. The residents of Ban Thapene reported that the collection of fuelwood and other NTFPs is permitted in protection forests while noting that hunting of wildlife is prohibited. However, in addition to the collection of NTFPs and fuelwood, the inhabitants of Ban

Yang also reported the rights to occasional hunting of small animals within the protection forests. Yet, the residents from both villages agreed on the rules regarding the use of production forests, where, according to them, all activities besides the unauthorised felling of large trees are permitted. Furthermore, Ban Thapene residents specified a threshold of 40 cm for tree diameter, beyond which permission for felling of trees in production forests is required. Conversely, Ban Yang residents indicated a higher threshold of 80 cm.

In the interviews, people from both villages discussed that the community members are involved in managing all three types of forests. They stated that DAFO, the governing authority, actively seeks the opinions and ideas of local people in forest management decisions regarding the nearby conservation and protection forests. Furthermore, the villagers oversee the production forests near their villages, with occasional support from DAFO in the form of technical assistance and provision of seedlings, among other forms of aid.

### ***3.2.3 Unpermitted activities in the forests***

In Ban Thapene, the residents noted that the transition in livelihoods from agriculture and NTFPs to tourism-based income has significantly reduced unauthorised activities done by the villagers. However, the residents highlighted ongoing incursions by individuals from neighbouring villages engaging in unauthorised activities within their forests. In Ban Yang, the villagers discussed the enforcement of sanctions and monetary penalties for individuals caught in illegal activities.

The members of both villages noted that the current sanctions and penalties prevent people from conducting unpermitted activities in the forest. The villagers from Ban Thapene advocated for an increase in forest patrols around the Kuang Si Waterfall from twice to three times a year. In contrast, the residents of Ban Yang expressed satisfaction with the current frequency of forest monitoring near their village, which they reported to be approximately 20 times a year, considering this level of surveillance as adequate.

### ***3.2.4 Utilisation purposes of each forest type***

The two villages exhibited contrasting approaches in utilising the three forest types. The residents of Ban Yang reported that NTFPs such as wild vegetables, mushrooms, bamboo shoots, and fuelwood are collected from all three types of forests. Additionally, they mentioned occasional timber extraction and animal hunting within protection forests. In contrast, the residents of Ban Thapene specified that NTFPs are sourced from production forests and occasionally from protection forests but never from conservation forests. Furthermore, they noted that timber extraction and wildlife hunting are only conducted in production forests. The members from both villages mentioned that the harvested NTFPs are primarily used for subsistence.

The most important NTFPs for Ban Thapene were bamboo shoots, wild vegetables, and fuelwood, while for Ban Yang, they were paper mulberry (*Broussonetia papyrifera*), broom grass (*Phragmites karka*), bamboo shoots, and fuelwood. For the residents of Ban Thapene, out of all the NTFPs, bamboo shoots are the most significant for gaining income. In contrast, for the people in Ban Yang, selling paper mulberry generates the most revenue. In Ban Thapene, harvested bamboo shoots are typically sold within the village. While in Ban Yang, the local people sell the paper mulberry to a middleman who transports it to Luang Prabang for further processing.

### ***3.2.5 Awareness and perceptions of biodiversity conservation***

The residents from both villages considered conserving and protecting forests to be very important. In Ban Thapene, the participants highlighted the significance of forest conservation for sustaining water sources and biodiversity, particularly in relation to the Kuang Si Waterfall. Moreover, in Ban Yang, the participants emphasised the critical role of forests in ensuring the availability of food and water and supporting local biodiversity.

In Ban Thapene, the residents emphasised the importance of forest conservation in Laos to mitigate natural hazards, stabilise rainfall patterns, and foster a favourable climate. Furthermore, in Ban Yang, the local people highlighted the role of forests in maintaining a stable climate and environment, and providing abundant sources of food and timber for construction activities. In both villages, residents agreed that the overall attitude towards forest protection and conservation in Luang Prabang is positive. In Ban Thapene, the residents expressed that increasing the area designated for conservation forests would be beneficial.

Regarding the awareness and education of the Lao forest law, residents of both Ban Thapene and Ban Yang reported that representatives from DAFO visit the villages annually to provide instruction on forest regulations, detailing permissible and prohibited activities. These sessions occur in the village meeting hall, with the head of each household attending. Subsequently, household heads relay the information to their families. Additionally, in Ban Thapene, the villagers noted that children learn about the significance of forests during their second year of primary school, typically around the age of eight. According to residents of both villages, there is a widespread awareness of the Lao forest law among all community members.

When discussing the advantages and disadvantages of residing near conservation and protection forests, the residents of Ban Thapene acknowledged a drawback regarding the loss of fishing areas due to conservation measures. However, they also highlighted several benefits, including a reliable water supply, rich biodiversity, and increased job opportunities and income from the growth of tourism in the area. In contrast, the residents of Ban Yang reported no downsides to living adjacent to conservation and protection forests. They only noted benefits, such as a good water supply, abundant biodiversity, and access to forest-derived food resources.

### ***3.2.6 Forests and livelihoods***

To address the challenges of living near conservation and protection forests, Ban Thapene residents emphasised the Lao government's supportive role in assisting their transition from traditional agricultural and NTFPs-based livelihoods to ecotourism-based income. This assistance facilitated the shift by providing training in entrepreneurial skills, empowering local people to seize opportunities in tourism and earn income from visitors. According to the local people, ecotourism in Ban Thapene has not only enhanced the livelihoods and income of the community but also contributed positively to conserving and protecting the local forests.

The local people in both villages hold a favourable view of tourists, recognising their essential role in generating income and livelihood opportunities for the community. According to the villagers in Ban Thapene, approximately 80 to 90 per cent of the local residents derive income from tourism-related activities, attributed to the popularity of the Kuang Si Waterfall. However, the interview participants also noted that the emergence of ecotourism in Ban Thapene has led to issues related to inadequate waste management in the village. The surge in tourism has strained existing waste management systems, exacerbated by limited landfill space, resulting in challenges with waste disposal.

In Ban Yang, the residents proposed that constructing a new road would improve connectivity between the village and the city of Luang Prabang, which would positively contribute to the conservation and protection of local forests. They anticipate that improved road access would facilitate more accessible transportation of agricultural products to the market in Luang Prabang. The interview participants believe this would generate more income and reduce reliance on hunting and using forest products, thereby alleviating pressure on forest resources.

Furthermore, the residents of Ban Yang expressed a desire to expand ecotourism opportunities in their village, highlighting its potential positive impact on their livelihoods

and the environment. They were eager to welcome more tourists to their village as it would enhance income opportunities, mentioning the possibility of selling souvenirs and handicrafts and working as guides to supplement their income. Currently, Ban Yang receives only about six groups of tourists annually, whereas the Kuang Si Waterfall attracts approximately 230,000 visitors to Ban Thapene annually.

### **3.3 DAFO interview**

#### ***3.3.1 Policies related to the conservation, protection, and production forests***

The forest officer from DAFO outlined the distinction between the three forest types in terms of permitted and prohibited activities. According to the officer, local people are legally prohibited from accessing conservation forests for any activities, including hunting wildlife, collecting NTFPs, or harvesting timber. Conversely, in protection forests, individuals are permitted to gather NTFPs and fuelwood for subsistence purposes, although commercial activities are prohibited. As for production forests, commercial timber extraction is prohibited, and individuals must obtain permission before felling trees exceeding 60 cm in DBH. Still, other activities such as hunting, collecting and selling NTFPs and fuelwood in production forests are permitted. However, despite these legal restrictions, the officer noted that unauthorised activities occur across all types of forests, especially in conservation and protection forests.

#### ***3.3.2 Monitoring***

The DAFO officer outlined the monitoring process, which involves three stages: planning the work, securing the necessary budget, and implementation. Additionally, the officer mentioned that the local people often report unauthorised activities to DAFO, which helps to enforce the forest regulations. The local people receive commissions from reporting such activities, creating a monitoring and enforcement system within the community.

The DAFO officer specified that during the previous REDD (Reducing Emissions from Deforestation and Forest Degradation) project in 2014, the DAFO was allocated sufficient funds to conduct forest monitoring twice a month. However, due to budget constraints, monitoring activities have since been reduced to once a year. According to the officer, the monitoring typically takes place in December, as January and February have the highest incidences of illegal logging.

According to the officer, the DAFO monitors tree felling and timber extraction, loss of forest cover, and occasionally illegal wildlife hunting. During the monitoring of illegal tree cutting, various parameters are documented, including DBH of the cut trees, the number of trees cut, the volume of timber extracted, the extent of land affected (measured in hectares), the individual responsible for the activity, the type of forest involved, and the zone where the unauthorised activity occurred.

The officer highlighted that the DAFO does not conduct biodiversity monitoring due to a lack of equipment, skills, and funding. Consequently, Lao government officers do not undertake the monitoring of certain species or their existence. While the primary responsibility for monitoring lies with the DAFO, it collaborates closely with local people, the Provincial Agriculture and Forestry Office (PAFO), and military personnel.

The monitoring records are stored as hard copies since there is no system for online documentation. Due to limited storage space, the records are archived for two years, after which they are routinely destroyed. Occasionally, records from five years prior may exist, but they are not retained beyond this timeframe.

### ***3.3.3 Management***

According to the officer, the primary goal of forest management is to preserve forest cover, as it ensures the availability of NTFPs and supports wildlife populations. The DAFO's role is to manage all three types of forests according to the Lao forest law,

educate local communities on the forest law, and provide guidance to ensure forest stewardship among residents. In addition to the local communities, the DAFO collaborates with various stakeholders, including the Ministry of Natural Resources and Environment, military personnel, and other law enforcement officers, depending on specific needs and circumstances.

The DAFO and the local communities share the responsibility for forest management. Local community members actively participate in managing production forests and collaborate with the DAFO in monitoring the conservation and protection forests. The officer emphasised that due to their proximity to the forests, the local communities are more capable of managing and monitoring forests compared to the government officers. Therefore, it is crucial that the local people actively participate in forest monitoring and conservation efforts. According to the officer, issues in the management of conservation and protection forests are addressed by the DAFO through intensified promotion of forest laws to villagers and by imposing stricter penalties.

#### ***3.3.4 Conservation planning***

Based on the input from the DAFO representative, the foremost priority in conservation efforts regarding resource allocation and focus is safeguarding the conservation forests. The second priority is the preservation of the protection forests, followed by conserving the habitats of endangered species and old-growth forests as the third priority.

The officer emphasised that DAFO considers local communities' needs and requirements during conservation planning. This includes ensuring that local people have sufficient access to land for fuelwood collection, obtaining building materials, and harvesting NTFPs. Additionally, each family has the right to request up to three cubic metres of timber and access to two hectares of land. The officer noted that the existing policies and forest laws do not hinder conservation planning or implementation. Instead, they facilitate cooperation between the DAFO and the local communities and enhance forest management procedures.

As stated by the DAFO officer, the DAFO adheres to the goals and plans set by the Lao government, aligning with global conservation targets and initiatives. The local people contribute to the restoration efforts by submitting their restoration plans to the PAFO, which in turn submits them to the DAFO, specifying the required number of seedlings and other resources. The local people carry out the restoration work, while the DAFO provides them with seedlings, necessary tools, and guidance.

### ***3.3.5 Conservation projects***

The DAFO has been participating in REDD projects in Laos, which aim to preserve forests and biodiversity. Although there are no ongoing conservation projects near the Kuang Si Waterfall, a REDD project was successfully implemented there in 2014. The officer highlighted that the REDD has been the most significant contributor to conservation efforts in the region.

The DAFO officer further emphasised that the involvement of local communities is an integral part of all conservation projects. In Laos, local residents participate in conservation-related meetings voluntarily and contribute to forest monitoring activities from which they receive compensation ranging from 50,000 to 100,000 kips per day, which is approximately 2.37 to 4.74 USD based on the currency exchange rate in late March 2024. According to the officer, the funding for conservation efforts remains significantly insufficient. The officer expressed the DAFO's strong commitment to increase monitoring efforts and undertake forest restoration initiatives if adequate financial resources are available.

### ***3.3.6 Effectiveness of forest conservation and protection***

According to the DAFO officer, the success of forest conservation and protection can be attributed to the local communities transitioning from agriculture to tourism-related businesses. For instance, many local people now craft handmade products to sell to tourists. Unfortunately, unauthorised activities in the forests persist. The officer noted that

illegal wildlife hunting is especially common, but identifying offenders proves challenging due to infrequent monitoring and the large extent of the forest area.

To enhance the effectiveness of conservation efforts, the DAFO officer suggested implementing crop rotation methods on agricultural land as an alternative to shifting cultivation. According to the officer, the crop rotation method would help maintain soil fertility on agricultural land, reducing the need for forest clearance for agricultural purposes. Additionally, the officer suggested that increased funding and monitoring would significantly improve forest conservation initiatives. Furthermore, the officer emphasised that successful conservation largely depends on adequate funding and the collaboration of local communities.

### ***3.3.7 Unpermitted activities in the protection and conservation forests***

The most frequently encountered unpermitted activities involve illegal tree felling and forest conversion to agricultural land. The DAFO officer noted that individuals involved in illegal activities, such as converting forested areas into agricultural land for farming purposes, believe they can avoid detection. Additionally, the officer highlighted that people convert forests because they are unaware that forested land, typically in hilly terrain, is often unsuitable for agriculture.

According to the DAFO officer, the degree of sanctions is determined by the type and severity of unpermitted activities. The officer provided insights into the enforcement measures for unauthorised forest activities. For example, while warnings are issued for cutting small individual trees, penalties are imposed for felling large trees or converting forested areas into alternative land uses. According to the forest law, the penalty for deforesting land is a minimum of six million kips (approximately 284 USD) per hectare. However, the officer noted that in practice, this amount triples to 18 million kips (approximately 853 USD) per hectare. Moreover, additional fines are imposed based on the size or volume of the felled trees. In cases of illegal hunting, possessing a firearm when committing illegal activities incurs a penalty of 1.5 million kips (approximately 71

USD), with the weapon being confiscated by the DAFO. If caught with a firearm and dead wildlife, the penalty increases to five million kips, and both the gun and the dead wildlife are confiscated. Moreover, individuals engaging in prohibited activities with a penalty exceeding 50 million kips (approximately 2370 USD) may face imprisonment in addition to paying the fines.

The DAFO officer recommended that facilitating shifts in local livelihoods away from agriculture and towards alternative occupations could effectively reduce the incidence of unpermitted activities. Additionally, the officer proposed that enhancing the promotion and enforcement of the Lao forest law coupled with heightened monitoring efforts would halt unpermitted activities in the forests.

### ***3.3.8 Education and awareness***

As explained by the DAFO officer, each year, the DAFO conducts outreach campaigns in every village to raise awareness about the Lao forest law. These campaigns consist of meetings, typically held between November and December, before the peak of the dry season when illegal activities are most prevalent. During these meetings, DAFO officers gather at the village's meeting hall to inform the heads of each family about the forest law. Subsequently, the heads of families disseminate this information to the rest of the family members, ensuring widespread awareness. Additionally, posters are placed in various locations in the forests to indicate the type and zone of the forest.

According to the DAFO officer, most people in Laos are aware of the Lao forest law. However, the officer noted that while younger individuals tend to be more knowledgeable about the forest law, some older community members may lack awareness, often due to illiteracy or belonging to an ethnic minority group where understanding of the Lao language may be limited.

To enhance public awareness of the importance of forests, the DAFO actively promotes the Lao forest law and assists the local communities in generating income from NTFPs. The officer noted that by demonstrating the economic potential of NTFPs, the DAFO aims to foster an understanding among local people that forests can serve as a sustainable source of income. This approach seeks to encourage communities to continue conserving forests while shifting away from reliance on extracting and selling timber and converting forests to agricultural land.

Furthermore, the DAFO officer highlighted that an improved education could help to raise awareness of conservation efforts and their importance. According to the DAFO officer, most people in Laos appreciate the conservation and protection of forests since many people fulfil their basic needs by accessing forests and forest products. However, the officer also noted that some individuals disapprove of forest conservation due to the restrictions on land use and access to natural resources.

## **4. DISCUSSION**

### **4.1 Forest inventory**

#### ***4.1.1 Natural regeneration***

The high abundance of seedlings and saplings in the conservation and production sites indicates a robust natural regeneration process. In contrast, the protection site was characterised by a low abundance of seedlings and saplings, indicating that the regeneration in the protection site is possibly impaired. Despite this trend, the protection site exhibited a slightly higher abundance of mature trees than the other two sites. Still, the total abundance of woody species was significantly lower in the protection site compared to the other sites. Specifically, the conservation site had 1.87 times as many woody individuals as the protection site, while the production site had an abundance of woody individuals 1.75 times as high as the protection site.

The low abundance of seedlings and saplings in the protection site can be attributed to various factors, including the site's physical characteristics and history. The protection site featured the steepest slope among the study sites, with an average incline of 28 per cent, and it faced southwest, receiving a substantial amount of direct sunlight. The combination of steep terrain and intense solar exposure likely contributes to high evaporation rates and drier soil conditions, posing challenges for seedling establishment and survival. Moreover, the rapid runoff of precipitation on steep slopes exacerbates the already poor moisture conditions, hindering seedling growth. Additionally, steep slopes are particularly susceptible to soil erosion, especially during heavy rainfall events, which are common in Laos during the wet season. Erosion removes topsoil and exposes the roots, further increasing the mortality rates of seedlings and saplings.

#### ***4.1.2 Forest structure***

A similar trend was observed in mean DBH and BA, as with the tree size class distribution and the total abundance of woody individuals, where the results between conservation and protection sites differed considerably. These findings suggest a structural difference between the two sites, challenging the validity of Hypothesis 1. However, the mean canopy openness, herbaceous species cover, and LAI were relatively similar between the conservation and protection sites and different from the production site. This indicates a structural similarity between conservation and protection forests, making Hypothesis 1 at least partially correct, with its validity depending on the specific structural attributes under consideration.

In the production site, an interesting result was observed, indicating that a higher canopy openness was associated with lower herbaceous species cover. This negative correlation between canopy openness and herbaceous species cover is likely influenced by the abundance of mature teak trees on the site and their phenological characteristics. During the dry season, the teak canopy is open due to the seasonal shedding of leaves. Teak trees annually shed a considerable amount of litter (Egunjobi 1974; Ola-Adams and Egunjobi 1992), forming a thick blanket that limits light penetration to the forest floor. As a result, the persistent shade inhibits the growth of herbaceous species under teak trees. Even in

the rainy season, when teak trees are fully foliated, their large leaves and dense canopy continue to cast significant shade, preventing light from reaching the forest floor.

The inventory measurements were conducted during the dry season when teak trees were absent of leaves, leading to a notably high canopy openness in the production site where teak was dominant. In sampling plots dominated by teak, the canopies were open, but the herbaceous species cover was low, likely attributed to the dense leaf litter on the forest floor. However, the production site exhibited heterogeneity and also had plots dominated by species other than teak. These plots had foliated canopies, resulting in lower canopy openness than teak-dominated plots. Despite the denser canopies, these plots also exhibited higher herbaceous species cover, likely due to the absence of thick leaf litter. The combination of the ecological characteristics of teak trees, the timing of the measurements, and the heterogeneity of the production forest likely played a significant role in the observed negative correlation between canopy openness and herbaceous species cover. This contrasting result in the correlation of canopy openness and herbaceous species cover in the production site underscores the need to consider site- and species-specific factors when interpreting ecological relationships.

#### ***4.1.3 Aboveground biomass***

The AGB measurements in the protection and production forests closely resembled those recorded in mixed deciduous forests in the Savannakhet Province, as reported by Vicharnakorn et al. (2014), where the average AGB was  $143.95 \text{ Mg ha}^{-1}$ . The conservation forest in this study had the highest value of AGB and the least signs of recent human impact. In contrast, signs of recent logging were abundant in both protection and production sites, likely contributing to their lower AGB values. The AGB in the conservation site was lower than those recorded for old-growth mixed deciduous forests by Yirdaw et al. (2019) in Vientiane prefecture and Savannakhet province, which were  $290.13$  and  $243.13 \text{ Mg ha}^{-1}$ , respectively. However, the old-growth forests are not entirely comparable to the relatively younger secondary forests of this study. An AGB value of  $215.14 \text{ Mg ha}^{-1}$  by Phomphoumy et al. (2023) was recorded in mixed deciduous forests in Phou Khao Khouay National Park, located about 40 kilometres northeast of Vientiane, the capital of Laos. This value closely aligns with the AGB value of the conservation site

of this study. However, it is important to interpret these findings cautiously, as the AGB is influenced by various factors, including stand age (Becknell and Powers 2014), topographic variables, and human impact (Salinas-Melgoza et al. 2018).

#### ***4.1.4 Floristic diversity***

The plot-based species richness in this study was lower than those found in the old-growth mixed deciduous forests by Yirdaw et al. (2019) within plots of the same size. Yirdaw et al. found the plot-based woody species richness to be 34.7 and 28.33 for 200 m<sup>2</sup> plots in the Vientiane prefecture and Savannakhet province, respectively. However, a study conducted by Phomphoumy et al. (2023) reported a total woody species richness of 126 when using a sampling size of two hectares in mixed deciduous forests in the Phou Khao Khouay National Park. This value closely resembles the woody species richness found in the conservation and protection sites of this study. Furthermore, Park et al. (2018) documented a total of 189 vascular plant species (angiosperms) in the Nam Ha National Biodiversity Conservation Area in Luang Nam Tha Province, northern Laos, during sampling conducted in the upper mixed deciduous forests. This species richness closely aligns with the number of woody species recorded in this study. However, it is worth noting that increasing the sampling size of this study might have resulted in the discovery of more woody species, as the species accumulation curves did not exhibit a significant levelling-off at any site.

The conservation and protection sites displayed a significantly higher richness of woody and dominant climber species, as well as a higher occurrence of dominant climber species compared to the production site. These results suggest that the conservation and protection sites exhibited higher diversity in woody and dominant climber species than the production site. Notably, the results from the Shannon and Simpson diversity indices also suggest that the conservation and protection sites have a higher woody species diversity than the production site. Additionally, the evenness of woody species at the protection site was notably higher than at the production site. However, the conservation site had a lower woody species evenness than the production sites, although the difference between the sites was not statistically significant. Furthermore, the number of dominant herbaceous species was notably lower in the protection site compared to the conservation

and production sites. In relation to Hypothesis 2, these results partially support the hypothesis, as the conservation and protection sites exhibited a higher woody and dominant climber species richness and occurrence of dominant climber species compared to the production site. However, the lower occurrence of dominant herbaceous species in the protection site contradicts the hypothesis, as does the low woody species evenness in the conservation site. Therefore, while some elements of Hypothesis 2 were validated, its overall applicability requires further refinement.

#### ***4.1.5 Species composition and similarity***

Regarding species composition, the conservation and protection sites exhibited the highest number of shared species, indicated by a high value of the Jaccard similarity coefficient. While these sites also shared many species with the production site, the overlap was notably less than that observed between the conservation and protection sites. However, despite these observations, the NMDS analysis did not reveal a significant difference in species composition among the three sites. This result is likely influenced by the similar topography and the location of the sites, as all sites were within a one-kilometre radius. The close proximity of the sites likely facilitates seed dispersal, which could explain the observed trend in the NMDS analysis. Regarding the occurrence of rare species, notably, the conservation site exhibited a higher number of singletons than the production site. Similarly, the protection site also had more singletons than the production site, though the difference was less pronounced than observed in the conservation site. Despite the NMDS ordination, the findings derived from the Jaccard coefficient and the count of rare species are consistent with Hypothesis 3. They indicate that the conservation and protection forests display a somewhat distinct species composition and a higher prevalence of rare species than the production site.

## **4.2 Interviews**

### ***4.2.1 Changes in the climate and weather patterns***

The villagers of Ban Thapene and Ban Yang reported an observed pattern of increasing temperatures and decreasing rainfall. This observed temperature increase aligns with

findings from Lamchin et al. (2018), who analysed 33 years of weather data (1982-2014) and concluded that this trend holds for northern Laos. However, according to their study, rainfall in northern Laos showed an increasing trend during the time period. Additionally, research by Shrestha et al. (2012) suggests that temperatures in northern Laos are projected to rise further under different climate change scenarios, and the total precipitation is also expected to increase. Also, Supharatid et al. (2021) projected that Laos will experience a significant rise in precipitation under different climate change scenarios. Moreover, the study expects that northern Laos, along with northern Vietnam and Myanmar, will experience the highest temperature increases across mainland Southeast Asia. While local observations and research support the trend of rising temperatures, the research does not support the observed trend of decreased rainfall in northern Laos. Furthermore, future projections suggest additional temperature increases and a significant increase in precipitation as climate change progresses. These future trends will likely affect the resilience of forests, access to NTFPs, and the livelihoods of local people (Ofoegbu et al. 2017).

#### ***4.2.2 Access rights and regulatory framework***

The interview results revealed significant differences between the two villages and the DAFO, particularly concerning access rights to different forest categories. The residents of Ban Thapene appeared to be more aligned with the forest laws outlined by the DAFO, with the primary distinction being the DBH threshold for timber requiring permission before felling. While the local people from Ban Thapene cited a threshold of 40 cm, the DAFO officer indicated it as 60 cm. In contrast, the residents of Ban Yang noted a much higher threshold of 80 cm. Furthermore, the residents of Ban Yang had their own interpretation of the forest law regarding permissible activities in each forest category. Their interpretation was considerably more permissive than the guidelines emphasised by the DAFO officer. Such inconsistencies highlight potential gaps in awareness and education regarding forest regulations among local communities, contrasting with the perceptions presented by the DAFO officer. This finding aligns with Hypothesis 4, revealing a gap between the understanding of forest regulations provided by the DAFO officer and the comprehension of local villagers, suggesting a limited awareness of forest laws among the local communities.

According to the DAFO officer, the Lao forest law is widely understood among most of the population, primarily due to annual outreach campaigns promoting awareness of the regulatory framework across various forest categories. However, despite the overall comprehension of many laws and regulations by the villagers in Ban Thapene and Ban Yang, numerous misunderstandings persist regarding permitted and prohibited activities. Research by Macura et al. (2011) found that individuals with good knowledge of the regulatory forest framework tend to exhibit greater appreciation for conservation areas and efforts. This underscores the importance of effectively promoting awareness of forest laws, which may result in more positive conservation outcomes. The DAFO officer also recommended increased promotion of the forest laws.

#### ***4.2.3 Environmental awareness and attitudes of the local people***

Studies conducted in developing countries (Mehta and Heinen 2001; Sodhi et al. 2010) have highlighted the positive impact of education, environmental outreach, and conservation programs on people's attitudes and willingness to conserve forests. In addition to promoting the forest law, the DAFO officer also emphasised the necessity for enhanced education and conservation campaigns to raise awareness about conservation efforts and their significance. However, inadequate funding was identified as the most significant barrier to the enhanced outreach and education efforts.

This study found that the interview participants from Ban Thapene and Ban Yang exhibited a positive attitude towards forest conservation and recognised several tangible benefits resulting from such efforts. Furthermore, the residents specified several positive impacts of conservation on the environment and their livelihoods while observing very few negative aspects. While the residents of Ban Yang did not report any adverse consequences of living near the conservation and protection forests, those of Ban Thapene noted a negative effect regarding their ability to fish around the village due to the establishment of the conservation area. Moreover, the residents of Ban Thapene expressed concerns regarding waste overflow, which is attributed to the high number of visitors at the Kuang Si Waterfall. Lau and Soukhy (2023) further emphasised the waste management issue in Ban Thapene, noting the potential negative impacts of inadequate waste management on human health, animal husbandry, and agricultural productivity.

While the members of both villages perceived many benefits from living next to conservation and protection forests, the residents of Ban Thapene also acknowledged some drawbacks, thereby aligning with Hypothesis 5.

Moreover, research by Sirivongs and Tsuchiya (2012) indicates that local communities' attitudes and perceptions towards conservation significantly influence their participation in conservation initiatives and the management of protected areas, leading to a higher likelihood of positive conservation outcomes. Interviews conducted with the local villagers and the DAFO officer revealed that the residents of the study villages are actively involved in managing and monitoring different forest categories and that the DAFO considers local communities' needs and requirements during conservation planning. This finding aligns with Brooks (2017), who conducted a comprehensive literature review of 136 community-based conservation projects and highlighted that local participation and environmental education, among other factors, contribute to positive outcomes benefitting both the environment and local communities. Moreover, studies have found that conservation efforts that incorporate the needs and aspirations of local people and provide socio-economic benefits are more likely to be sustainable and yield positive long-term results (Kettle 2010; Oldekop et al. 2016).

#### ***4.2.4 Forests and livelihoods***

The residents of Ban Thapene have observed a notable shift in livelihood patterns, transitioning from agricultural and NTFPs-based income to tourism-related activities, which has led to a significant decrease in unpermitted activities among villagers. It was evident that the establishment of the Kuang Si Waterfall Park played a pivotal role in this transition, providing a source of tourism to the village. Moreover, the support from the Lao government, including training programs and empowerment initiatives, has enabled local people to capitalise on opportunities in the tourism sector and generate income from visitors. The residents of Ban Thapene observed that these initiatives have been highly beneficial, benefitting the local people and the environment.

Moreover, the DAFO officer emphasised the importance of transitioning local livelihoods from agriculture and NTFP-based activities to other forms of income generation, such as

tourism-related activities or other types of businesses, suggesting that such shifts could effectively reduce unpermitted activities. These findings align with other research (Mehta and Heinen 2001; Nyaupane and Poudel 2011), which highlights the correlation between local community benefits from tourism and their positive attitudes towards conservation efforts, ultimately leading to better conservation outcomes. Similarly, research conducted by Sodhi et al. (2010) in developing countries across Southeast Asia concluded that enhancing conservation outcomes requires focusing on providing alternative livelihood opportunities, as this reduces people's dependence on natural resources. In this study, both the DAFO interview and focus group discussions suggested that the transition from agriculture-based livelihoods to tourism-based ones has already played a significant role in contributing to the success of the previous conservation efforts, especially in Ban Thapene. However, reliance on tourism as a livelihood is also criticised, as it may lead to weak sustainability of rural livelihoods (Su et al. 2018).

This study observed considerable differences between the villages regarding their livelihood opportunities. The residents of Ban Yang demonstrated a strong reliance on access to forests and NTFPs for their livelihoods. In Ban Yang, the local people also sold some of the harvested NTFPs outside the village to generate income. Conversely, the residents of Ban Thapene primarily utilised NTFPs within the village, and most people generated income from tourism-related activities. These findings align with those of Foppes and Kethpanh (1997; 2004) suggesting that low-income households, especially those with restricted access to markets, depend more on access to forests and forest products.

#### ***4.2.5 Ecosystem services and perceived benefits of conservation***

In Ban Yang, the residents emphasised the significance of forest conservation for provisioning services, particularly highlighting its role in ensuring food security and generating income. Conversely, residents of Ban Thapene focused more on the importance of conservation in relation to regulating and supporting ecosystem services. This finding suggests that residents of Ban Yang may prioritise different aspects of conservation compared to those of Ban Thapene. These findings further align with

Hypothesis 6, as they indicate that there are some variances in forest product utilisation and perceptions of forest conservation between the villages.

Still, access to forests and NTFPs seemed to be highly important for the residents of both villages and attitudes towards conservation were positive across the villages. Moreover, the observed increase in NTFPs near the study villages was credited to conservation initiatives in the area. The perceived positive impacts of conservation, such as enhanced availability of NTFPs, have likely contributed to the favourable attitudes of the residents of Ban Thapene and Ban Yang towards conservation.

### **4.3 Linkages between the forest inventory and interview results**

Through the interviews, it became evident that local communities and social aspects are intrinsically linked with the conditions of the forests. This relationship seemed to be reciprocal: communities, their socioeconomic factors, and well-being impact the forests and biodiversity, and in turn, the forests and their diversity influence the local people, their livelihoods and well-being through ecosystem services and access to forest products. The previous conservation efforts that expanded forest cover in the study area were directly linked to increased availability of NTFPs, positively impacting the local people and their well-being. Moreover, the governmental initiatives that assisted local people in transitioning from traditional agriculture and NTFP-based livelihoods to ecotourism-based activities improved livelihoods and income, while also contributing positively to the conservation and protection of local forests. These results align with the findings of Miller et al. (2012), who emphasised the interconnectedness of social and environmental systems, suggesting that efforts leading to favourable social outcomes also result in positive environmental effects, and vice versa.

Furthermore, the interviews unveiled several factors that could have positively influenced the local conservation efforts and forests surrounding the Kuang Si Waterfall. These factors include local people's positive attitudes and perceptions towards conservation, their active participation and engagement in forest management and monitoring, and the DAFO's consideration of the local communities' needs and requirements in conservation planning. Several studies (Ihemezie et al. 2021; Macura et al. 2011; Mehta and Heinen

2001; Sirivongs and Tsuchiya 2012) have underscored the pivotal role of local people's attitudes and perception of conservation in fostering positive conservation outcomes. Additionally, active participation and involvement of local communities in forest management and monitoring, as highlighted by Brooks (2017), have been consistently associated with favourable conservation outcomes. Moreover, considering local communities' needs and requirements in conservation planning has been linked to enhancing the possibility of sustainable and positive long-term conservation results (Kettle 2010; Oldekop et al. 2016). These factors have most likely positively impacted the conservation efforts in the Kuang Si Waterfall area and contributed to the high floristic diversity found in the conservation and protection sites of this study.

While the interviews revealed numerous factors that have potentially benefitted conservation efforts and the local forests, they also uncovered factors that likely have had a negative impact on the forests in the study area. These factors include a lack of legal awareness regarding the Lao forest law, limited alternative livelihood opportunities, and insufficient funding for conservation. The lack of legal awareness is known to influence the behaviours of local people (Gençay and Mercimek 2019), which, in turn, could negatively affect the surrounding forests, their structure, and floristic diversity. Moreover, limited alternative livelihood opportunities in developing countries place significant pressure on forests (Sodhi et al. 2010), which could have further impacted the local forests. Additionally, according to the DAFO officer, insufficient funding hinders the continuation of conservation efforts and monitoring activities, which also likely has adverse effects on the local forests. Consequently, these factors may have also been reflected in the forest inventory results of this study, and they should be addressed for more successful conservation outcomes.

Despite the relatively small sample size of the interviews, conducting them as part of this study was essential to understand how the social aspects and human behaviour might influence the current forest conditions and biodiversity maintenance, and to address the effectiveness and success of conservation efforts (Reddy et al. 2017). Moreover, given that the attitudes, values, and actions of local communities are strongly associated with the success of conservation initiatives (Bennett et al. 2017; De Snoo et al. 2013; Dietz et al. 2005; Ihemezie et al. 2021; Reddy et al. 2017), overlooking these social factors in

conservation-related research would have been detrimental. Overall, the interviews conducted in this study provided valuable insights into the social context and socioeconomic factors, enhancing the overall understanding of the elements influencing the current state of the study forests and highlighting the areas that require further attention for more effective conservation outcomes.

#### **4.4 Limitations of the study**

Although many aspects of the study proceeded as intended, several limitations emerged. Initially, the intention was to incorporate the scientific names of the woody species into the study. However, the challenges encountered in finding the corresponding scientific names and reliably identifying these names led to their exclusion. In the field, the species were identified, their Lao names were recorded, and images of the plants were captured to further help with the scientific species name identification. The plan was to utilise Lao plant checklists later to match these names with their corresponding scientific names.

Unfortunately, this approach proved unsuccessful for numerous species. Even if many of the corresponding scientific names were found, their accuracy was compromised due to the limited information available, relying solely on the Lao names and captured images without physical samples for verification. Consequently, the difficult decision was made to omit mentioning the species names in this study. However, if the identification of the species' scientific names had been possible, it would have brought a lot of important information to the study, including the potential identification of IUCN red-listed species. In hindsight, engaging a local botanist to gather samples of the species discovered in the field would have been advantageous. Their expertise could have significantly contributed to a successful and accurate identification of the scientific names of the species.

Furthermore, the lack of levelling-off of the woody species accumulation curves indicates that the sampling efforts were insufficient to capture all woody species in the different sites. Despite conducting sampling across 1.2 hectares, it is evident that expanding the sample size, ideally by doubling it, would have been beneficial given unrestricted time and funding.

Similarly, increasing the sampling efforts for the interviews could have resulted in more robust findings and improved the validity of the conclusions. Only one focus group discussion was conducted in each study village, with eight to ten participants of varying ages and genders in each group. The limited number of interview participants may affect the comprehensive representation of the community's attitudes and behaviours towards conservation efforts. Additionally, the DAFO interview was also conducted with only one DAFO officer. However, with larger resources, conducting individual interviews with multiple households across different local communities and larger-scale interviews with several DAFO officers could have provided more in-depth insights and yielded more conclusive results. Furthermore, increased interview sampling efforts would have facilitated the application of qualitative analysis methods, such as thematic analysis, enabling a more comprehensive and thorough examination of the interview results.

Moreover, there is a potential for biases in the interviews, particularly within the focus group discussions. Participants who voluntarily joined the interviews may have had pre-existing interests or positive attitudes towards conservation, resulting in self-selection bias. This could have led to an emphasis on positive perceptions and perspectives regarding conservation. Additionally, the interviews included sensitive topics, such as illegal activities, and participants may have felt hesitant to fully express their opinions or experiences in the interview setting. Consequently, some interviewees may have omitted certain viewpoints or withheld information, further leading to a partial representation of the community's attitudes and behaviours towards conservation efforts. These biases may impact the overall findings and conclusions of the study, highlighting the importance of interpreting the results with caution.

## **5. CONCLUSION**

### **5.1 Inventory**

In the study, structural differences between the Lao forest categories were evident, notably with the conservation and protection sites showing higher similarity to each other compared to the production site. Moreover, the conservation and protection sites

demonstrated significantly higher woody and dominant climber species richness and occurrence of dominant climber species than the production site. Additionally, the results from the Shannon and Simpson diversity indices indicated that the conservation and protection forests had a higher diversity of woody species compared to the production site. Furthermore, the conservation and protection sites exhibited the highest number of shared species and were characterised by a higher occurrence of rare species than the production forest.

Despite the significant differences observed between the three forest categories in this study, it is essential to acknowledge the limited sampled area, totalling 1.2 hectares. Consequently, the findings presented here can offer insights into the distinctions between Lao forest categories, however, they cannot be generalised nationally. To draw more comprehensive conclusions regarding structural and floristic diversity differences across the Lao forest categories, broader sampling efforts across Laos are necessary. It is anticipated that substantial variations exist between different forest categories and within them. While this study provides guidelines for potential differences between the Lao forest categories, further research is essential to fully comprehend the extent of these differences between and within the forest categories.

Moreover, it is worth noting that due to the close proximity between the sites, the production site of this study might, among other reasons, have exhibited a higher-than-typical species richness. This proximity to the conservation and protection forests likely facilitated seed dispersal, enabling the presence of many species that might otherwise be absent from typical production forests in Laos. It can be anticipated that production forests situated far from conservation and protection forests may display a less diverse floristic composition. Considering future management guidelines, it could be advantageous for production forests to be located near conservation and protection forests to promote diversity within the production forests. Furthermore, providing ecological connectivity between the different forest categories could enhance the diversity of different flora and fauna, further promoting the maintenance of ecosystem functions and the resilience of ecosystems at a landscape scale. These management suggestions not only have the potential to enhance ecological and environmental sustainability but also to

significantly improve the well-being of local communities and ensure the sustainability of their livelihoods.

## **5.2 Interviews**

In addition to the forest inventory, the interviews with the local villagers and the forest authority also provided valuable insights into the factors influencing the study forests and their conservation. The interviews revealed a limited awareness of the Lao forest law among the residents of the study villages. However, the interview participants from Ban Thapene and Ban Yang exhibited notably positive attitudes toward forest conservation, citing several conservation benefits, such as enhanced availability of NTFPs and maintained ecosystem services. Nevertheless, the residents of Ban Thapene also acknowledged some drawbacks of living next to a conservation forest. Moreover, while access to forests and NTFPs appeared to be highly important for the residents of both villages, there were some differences between the villages regarding forest product utilisation and perceptions of forest conservation. In Ban Yang, where access to markets is more restricted and income levels are notably lower, people were more heavily dependent on forests and the NTFPs for their livelihood activities.

The interviews with the local villagers and the DAFO officer also revealed that the local communities are actively involved in forest management and monitoring. This active participation enhances the potential for effective conservation efforts and long-term outcomes. However, underlying socio-economic challenges, such as the lack of alternative livelihood opportunities, emerged as critical barriers to more effective conservation. The interviews found that this lack of livelihood opportunities compels some individuals to engage in unpermitted activities within the conservation and protection forests, undermining conservation efforts.

Hence, it became evident that addressing socio-economic factors is critical for achieving sustainable and long-term conservation outcomes. Providing alternative livelihood opportunities can alleviate pressure on forest resources while improving local communities' well-being. By providing support and implementing initiatives aimed at diversifying livelihood activities, such as training in eco-tourism, promoting sustainable

agricultural and land management practices, offering educational programs, and supporting the development of small businesses and entrepreneurial skills, communities can expand their income sources. This reduces reliance on forests and agricultural products, fostering positive conservation outcomes. Therefore, future conservation efforts should prioritise both environmental and socio-economic objectives, creating win-win solutions that benefit both people and nature.

According to the DAFO officer, lack of funding is one of the main constraints to conducting effective conservation efforts, highlighting the critical need for financial resources in achieving sustainable forest management. In addition, the officer highlighted the need to enhance the promotion and enforcement of the Lao forest law and increase monitoring efforts to prevent unpermitted activities, which would be possible with increased funding. Furthermore, the officer recommended implementing crop rotation methods as an alternative to shifting cultivation to promote sustainable land use and reduce the conversion of forests into agricultural land. Moreover, the officer emphasised that collaboration with the local communities is necessary for successful conservation outcomes.

This research emphasises the importance of prioritising the needs of local communities and their livelihoods in conservation planning. In developing countries, securing sustainable livelihoods for the local communities should be a central focus of conservation initiatives, as enhancing the local people's overall well-being fosters positive long-term conservation outcomes. While tourism offers a promising alternative livelihood, it is vital to prevent overreliance on it, considering the associated risks. In areas experiencing a surge in tourism, initiatives should focus on developing infrastructure to accommodate the growing number of visitors. This includes improvements in road networks and waste management systems, among other essential services, to meet the demands of increased tourism.

Moreover, targeted initiatives and assistance should focus on providing education, training, and resources for sustainable land management, agriculture, and entrepreneurship to empower local communities. Diversification of income sources is critical to enhancing economic resilience and alleviating pressure on natural resources

and the environment. In conclusion, prioritising the socio-economic needs of local communities and implementing diversified and sustainable livelihood strategies are essential for achieving successful conservation outcomes in Laos. Looking ahead, conservation efforts and initiatives should emphasise enhancing socio-economic aspects and local well-being alongside environmental concerns. This integrated approach ensures the sustainability of natural ecosystems and local livelihoods, strengthening the potential for sustainable, long-term positive outcomes.

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## 7.2 Appendix 2

### Focus group discussion form

#### 1. Site history and the recent changes

1.1 Has there been any changes in weather patterns in the past 10 years? (2013-2023)

- What sort of changes? E.g. rainfall, rain patterns, temperature, storms, landslides, natural hazards, drought, etc.?

1.2 Has there been any changes in the forest conditions in the past 10 years? (2013-2023)

- What sort of changes? E.g. changes in flora and fauna species, something else? Which species?
- Why is the change occurring?

1.3 Has there been an increase or decrease in the availability of forest products, especially in NTFPs (non-timber forest products)?

- If yes, which products have been affected?
- Why is the change occurring?

1.4 When did the nearby conservation forest become a conservation forest?

- What was the land before it became a conservation forest?

1.5 When did the nearby protection forest become a protection forest?

- What was the land before it became a protection forest?

1.6 When did the nearby production forest become a production forest?

- What was the land before it became a production forest?

#### 2. Access rights

2.1 Who can access the conservation, protection, and production forests?

2.2 What is allowed to do in each forest type, and what is not allowed?

2.3 Do some actions, like timber extraction or collecting items for selling, require permission?

- If yes, who gives the permission and decides about it?
- On what occasion can one get such permission?

### 3. Unpermitted activities in the forests

3.1 What happens if someone does something that is not allowed to do in the forest?

3.2 Who is enforcing the forest access and utilisation laws, and how?

- Warning, fines, penalties, imprisonment?

3.3 Are the sanctions reasonable or not?

3.4 Are the sanctions stopping or preventing people from doing unpermitted activities in the forests?

3.5 How often is someone guarding the nearby forests around the village?

- Is the amount reasonable, or should it be increased or decreased?

### 4. Utilisation purposes of each forest type

4.1 What sort of products are collected from each forest type?

- For each product, are they collected for subsistence, selling purposes, or both?
- What are the most important forest products for subsistence use?
- What are the most important forest products for selling and gaining income?

4.2 Who is buying the forest products?

- Local people, export to Lao cities, or abroad to Thailand or China, etc.?

4.3 Who manages each forest type?

4.4 Is DAFO or another authority asking the local people for their opinion or perception on managing the forest sites?

4.5 Who owns the production forest?

4.6 Who decides what is grown, harvested, used, and sold from the production forest next to the village?

### 5. Awareness and perceptions of biodiversity conservation

5.1 Is it important to conserve and protect forests?

- If yes, why?

5.2 Should Laos have protection and conservation forests?

- Why?

5.3 What is the general view of forest protection and conservation in Luang Prabang?

5.4 Does DAFO, other authorities, or the school teach people about the forests and issues related to biodiversity loss and species?

- If such education is given, how old are people when they learn about it?

5.5 Does everyone in the village know forest law, including what can and should not be done in the conservation, protection, and production forests?

5.6 How do people learn these rules, and at what age?

5.7 What are the positives and negatives of living next to the protection and conservation forests?

5.8 Could the government do something to mitigate the adverse effects of living next to protection and conservation forests?

- If yes, would such action make forest conservation/protection more effective?

## 6. Impacts of ecotourism

6.1 How are the tourists perceived?

- Do the local people like having tourists in the village?

6.2 Does ecotourism have an impact (positive or negative) on the environment?

6.3 Does ecotourism contribute to the income or livelihoods of the village?

- How are the benefits distributed? Between everyone or just some people?

6.4 Do you think that ecotourism would help other villages gain income, like Ban Thapene?

## 7.3 Appendix 3

### DAFO interview form

#### 1. Policies related to the conservation protection, and production forests

- 1.1 What is the purpose of each forest type?
- 1.2 What is the difference between conservation and protection forests?
- 1.3 Who can access conservation, protection, and production forests?
- 1.4 What activities are not permitted in the three different forest types?
- 1.5 How much of the forests in Laos or Luang Prabang are conservation, protection, and production forests?
- 1.6 What is DAFO's role in managing the conservation, protection, and production forests?
- 1.7 Which institutions, if any, are also involved in managing the conservation, protection, and production forests?

#### 2. Monitoring

- 2.1 How are the three different forest types monitored?
- 2.2 How often are they being monitored?
- 2.3 Who is responsible for the monitoring?
- 2.4 Is there documentation related to monitoring activities?
- 2.5 What is monitored?
  - Species existence/sightings, other indicators of biodiversity, unpermitted activities done in the areas....?
  - What type of monitoring is being used?
- 2.6 What is documented?
- 2.7 Is there an archive of documents from past monitoring efforts?
- 2.8 How many documents there are related to the site history and usage of the forest areas?
  - How far do they date back?

### 3. Management

- 3.1 Who/What department is responsible for managing the conservation, protection, and production forests?
- 3.2 What are being managed in each of the forest types?
- 3.3 How much can the local people manage the different types of forests?
  - Especially in production forests, are they given free hands on what they do with the land area, or are there rules and regulations to it?
- 3.4 Are the local people involved in managing the protection and conservation forests?
- 3.5 When problems arise at the conservation management level, how are they diagnosed, and are there any efforts to implement adaptive management?

### 4. Conservation planning

- 4.1 Are there any specific conservation goals, are they related to any of the global conservation targets?
- 4.2 How are the conservation efforts and management planned?
- 4.3 Is priority setting in conservation being implemented into the planning?
  - If yes, how?
- 4.4 Are the local people's needs (e.g. for fuelwood, building materials and forest food) and development being integrated into the planning?
- 4.5 Are any policies or legislations making conservation efforts difficult to plan or implement?
  - If yes, what are they, and how do they complicate things?
- 4.6 Are there any policies or legislation that would make conservation planning and implementation more successful?
  - If yes, what would they be?

### 5. Conservation projects

- 5.1 What sort of conservation projects are being done by DAFO?
- 5.2 What are the recent projects in the Kaung Si Waterfall area?
- 5.3 Are the local people involved in the conservation projects?
- 5.4 In conservation projects, how is the information passed down in the DAFO from the manager level to the person working in the field?

5.5 Who funds the conservation activities and projects? / Where does the funding come from for all conservation and forest protection efforts?

- Are there international funds available from bigger NGOs or elsewhere?
- Are there any international experts from overseas coming for conservation projects, management or planning in Laos?

5.6 How much are there funds for conservation efforts?

5.7 Is there enough funding?

5.8 If there were more funding, what projects would be undertaken?

## 6. Effectiveness of forest conservation and protection

6.1 How well is the conservation and protection working?

- Is there enough monitoring in place to know for sure?

6.2 Is it common for people to misuse forests and engage in prohibited activities, such as tree cutting and hunting, in protection and conservation forests?

- How common?

6.3 What could be done to make conservation and forest protection more effective?

6.4 What would help to improve the protection/conservation of the forests?

6.5 What are the main restrictive attributes to successful conservation?

## 7. Unpermitted activities in the protection and conservation forests

7.1 How often is someone guarding the forests and making people to compensate in case unpermitted activities are done?

7.2 What sort of unpermitted activities are common in the protection and conservation forests?

7.3 Why do people do unpermitted activities in the protection and conservation forests?

7.4 What sort of sanctions do people get if they do unpermitted activities in the forests?

- Warnings, fines, penalties, imprisonment?

7.5 What could we do to decrease unpermitted activities in the protection and conservation forests?

## 8. Education and awareness

- 8.1 How are the conservation and protection needs and efforts communicated to local people?
- 8.2 Do the local people know what is okay to do and what is not in the conservation and protection forests?
- 8.3 How is the information passed on to them?
- 8.4 What is the level of public awareness regarding forest conservation and protection?
- 8.5 Are there any efforts made to increase public awareness of forest conservation and protection?
  - If yes, what efforts?
- 8.6 How could we increase the awareness of conservation among the local people?
- 8.7 What is the general view of people in Laos on forest conservation and protection?