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Bioprospecting of Edible Fruit and Ethnomedicinal Trees: Pathways for Conservation in the UNESCO Biosphere of Apayao, Philippines

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ABSTRACT

This study was undertaken in the upper and lower municipalities of Apayao Province, namely Luna, Pudtol, Kabugao, and Calanasan, integrated in the Northern Luzon forest ecosystems. It sought to characterize the external physical traits and perform in vitro analysis of selected five (5) edible fruit and ethnomedicinal trees, focusing on their ecological status, chemical composition, and conservation significance. Specifically, the research aimed to determine the phytochemical composition and cytotoxicity patterns of these species, to identify the environmental threats compromising their survival, and to propose policy recommendations in support of biodiversity conservation and sustainable forest governance. Fieldwork, tree species identification, habitat characterization, and preparation of specimens for laboratory analyses were done. Key Informant Interviews were employed to incorporate community-based ecological knowledge in relation to observed threats. The approach is through open-ended questions, flexible discussion, and follow-up probing. Morphological characterization and phytochemical screening revealed the presence of secondary metabolites such as tannins, flavonoids, and saponins, while cytotoxicity assays demonstrated moderate to high inhibition of breast cancer cell proliferation. These findings underscore the possibility of health advantages of the province's forest natural resources. Results further revealed that the ecological status of the studied trees ranges from vulnerable and threatened to least concern, showing different levels of conservation priority. Major threats documented included extreme weather events (typhoons, droughts), the occurrence of pests and diseases, and manmade induced pressures such as forest clearing. Policy recommendations were crafted to support local ordinances that strengthen conservation and protection measures.

Keywords: Ethnomedicinal Trees; Phytochemical Composition; Biodiversity; Sustainable Forest Management

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1. Introduction

The Philippines is considered one of the world's biodiversity hotspots due to its diverse ecosystems, ranging from tropical rainforests and mangrove swamps to coral reefs and mountain ranges. This biodiversity is supported by its unique geography, with over 7,100 islands that host a wide variety of flora and fauna. With this, the country is regarded as one of the 18 megadiverse countries, hosting extraordinary levels of biodiversity and endemism [1].

The Cordillera Administrative Region of the country is one of its regions that is characterized by diverse ecosystems due to its mountainous terrain. These ecosystems range from montane forests and grasslands to mossy forests and high-altitude scrublands. The biodiversity of the Cordillera region is intertwined with the cultural practices and livelihoods of indigenous communities. Many plant species in the region have cultural significance and are used for traditional medicine, rituals, handicrafts, and food. There were 305 indigenous plant species utilized across the Cordillera Administrative Region in community healthcare, farming, food, rituals, and more. About 27% are used in local community healthcare, demonstrating ethnomedicinal importance [2].

Apayao, as the fourth UNESCO Biosphere Reserve in the Philippines, recognizes its role in biodiversity conservation and community empowerment is characterized by its rugged terrain, lush forests, and scenic landscapes. It is part of the Cordillera Administrative Region, known for its biodiversity, montane ecosystems, and as the watershed cradle of the North. Thus, it is rich in ethnomedicinal plants and trees that are traditionally used by indigenous communities for various medicinal purposes.

Ethnomedicinal trees have a significant role in terms of ecosystem services, especially in rural and indigenous communities. These services traversed the provisioning, regulating, supporting, and cultural services. As provisioning services, ethnomedicinal trees serve as sources of food, fuel, and materials. For instance, the Manobo and Higaonon communities in Esperanza, Agusan del Sur, have identified 43 medicinal tree species, like *Cinnamomum mercadoi* and *Ficus concinna*. These species are used to manage illnesses such as fevers and digestive issues [3]. For regulating services, it is common knowledge that trees can sequester carbon, helping reduce climate-related impacts. It also prevents soil erosion in steep upland areas through their root systems, where indigenous people live. Dapar 2020 claimed that trees contribute to maintaining the water cycle, ensuring the availability of clean water sources for communities. As supporting services, ethnomedicinal trees support a diverse flora and fauna species, sustaining the ecological stability system. For example, the rich biodiversity of Sibuyan Island, which includes various endemic plant species, is partially attributed to the presence of diverse tree species [4]. Moreover, the cultural services of ethnomedicinal trees are the main cultural uniqueness among indigenous people. One example is the Panay Bukidnon community in Iloilo, they have a rich repository of knowledge regarding medicinal plants that is transmitted through generations [5].

Ethnomedicinal trees are commonly used in Apayao as a remedy for ailments. Among the plants used by the Isnags, several are endemic to the Philippines; these include: Agathis philippinensis (Almaciga), Dillenia philippinensis, Shorea negrosensis, Croton consanguineus, and Toona calantas (Philippine mahogany), which are also part of their medicinal plant repertoire [6]. Maximizing the uses of plants and trees involves understanding their chemical properties, which can reveal their potential applications in various industries such as pharmaceuticals, cosmetics, agriculture, and materials science. The study on chemical contents will serve as a guide for the community to verify whether their knowledge of its use is accurate, helping them avoid overdosing. The chemical profiling of indigenous ethnomedicinal trees—including quantification of phenolics and identification of compounds like tannins, steroids, and flavonoids—allows communities to better standardize usage, assess medicinal potency, and reduce risks of overdosing when utilizing traditional remedies [7].

Furthermore, understanding the chemical profiles of ethnomedicinal trees contributes to biodiversity conservation by highlighting species with high medicinal and economic value that require protection [8].

Exploring and understanding the morphological and chemical properties of plants and trees can unlock their full potential for diverse applications. Morphological features remain the key basis of ethnobotanical identification before chemical evaluation [9]. Chemical analysis is crucial in ensuring the safety and efficacy of medicinal plants, including trees [10]. Trees and plants used in ethnomedicine contain phytochemicals that support their traditional applications [11]. Due to limited information regarding the chemical composition of trees thriving in the province of Apayao, awareness of the morphological and chemical properties of these trees is crucial for both cultural practices and scientific research. The result will aid in the correct utilization of the trees for ethnomedicinal purposes. Studying ethnomedicinal trees and edible fruits is important for preserving traditional knowledge, promoting food security, and discovering bioactive compounds for health applications. These trees and fruits are often used by local communities to treat various ailments, making them a vital part of their cultural heritage and primary healthcare. Learning these plants also helps in conservation efforts, particularly for species that are threatened or endemic, ensuring sustainable use while maintaining biodiversity [12]. Additionally, integrating ethnomedicinal knowledge with scientific research can lead to novel drug discovery, functional foods, and improved community health strategies [13].

Furthermore, with growing environmental challenges, such as climate change, habitat loss, and overexploitation, the long-term sustainability of these resources is increasingly at risk. By integrating ethnobotanical study into sustainable resource management, strategies for conservation can be better supported, ensuring the protection of these species while supporting the livelihoods of local communities. Lastly, valuing their role in ecosystem stability enhances community climate resilience by conserving ecological systems that act as buffers against climate hazards.

With this, it is imperative to recommend a policy for the protection and management in terms of utilization and conservation of these ethnomedicinal trees from all forces of threats to sustain the ecological services brought about by these tree species. This approach not only supports biodiversity conservation but also improves the coping ability of communities under changing environmental conditions.

This research aimed to characterize morphologically the selected edible and ethnomedicinal trees commonly used by local communities; analyze the phytochemical and cytotoxicity contents; identify the threats faced by the selected edible and ethnomedicinal trees, and propose policy recommendations for the protection and conservation of the native and ethnomedicinal trees.

2. Materials and Methods

2.1. Location

This research was conducted in the forest landscape of Apayao province, particularly in the municipalities of Pudtol (Barangay Upper Maton), Luna (Barangay Marag), Poblacion Kabugao, and Calanasan (Barangay Eleazar), Apayao (**Figure 1**).

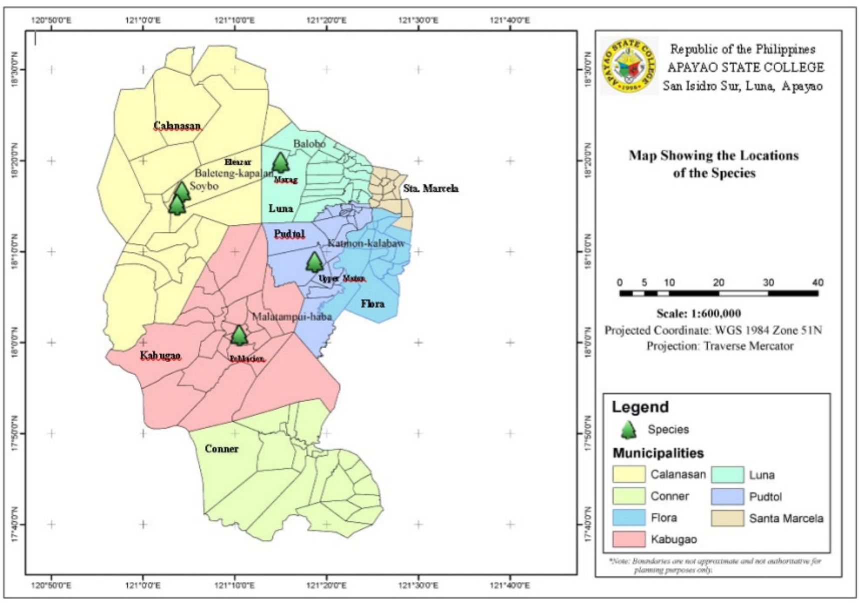

Figure 1. Map of the Study Sites in Apayao Province.

2.2. Data Gathering Procedure, Sources, and Methods

Data gathering of the edible and ethnomedicinal trees was done through field work, specifically GPS point marking and photographic documentation at the forested areas of the municipality of Pudtol (Barangay Upper Maton), Luna (Barangay Marag), Poblacion Kabugao, and Calanasan, Barangay Eleazar, Apayao. The locations of the five (5) selected trees were identified through geotagging, including the coordinates. This is to establish precise spatial information for mapping, monitoring, and visualization of ecological patterns, which are crucial for conservation planning, disaster risk reduction, and sustainable resource management.

During the fieldwork, relevant information on tree species was systematically documented to ensure accuracy and completeness. The following data were gathered for each species encountered: exact location and GPS coordinates, local name of the tree species, documented uses, Photo documentation for identification and record-keeping, and observed threats faced by the tree species.

2.2.1. On Morphological Characterization of the Edible Trees and Ethnomedicinal Trees

As part of the taxonomic process, five (5) tree species were identified based on their local, common, scientific names, and family names. In terms of morphological characterization, tree species were described based on the crown structure, foliage arrangement, leaf shape, fruit, and flower types. Other information noted was habitat, phenology, uses, propagation, timber classification, and conservation status using the IUCN Red List of Threatened Species and DAO 2007-01, S. 2007 and 11.

2.2.2. On Chemical Analysis of the Edible and Ethnomedicinal Trees

Phytochemical Analysis

The following are steps used in preparation for the extraction of leaves for phytochemical analysis:

1. Air drying of collected leaf samples for seven (7) days to ensure that no moisture content.
2. Dried leaves were chopped into small pieces and weighed;
3. From the weighed samples, 100 g of each species were put in containers and treated with 95% methyl alcohol of 800 mL and stored for 48 h at a cold temperature of 0–5 degrees centigrade;
4. The extraction was brought to DOST-Tuguegarao for phytochemical analysis. The method used was based on Guevarra et.al (2005) for qualitative phytochemical tests. The use of colorimetric reactions to test the presence/absence of specific compound groups was considered.

The following were typical tests done:

Flavonoids: from the prepared extract of the five tree species, the addition of a diluted solution of 2–3 drops of 10% sodium hydroxide (NaOH) and hydrochloric acid (HCl) was done. The addition of NaOH to the extracts of all five tree species produced a yellow color, which turned pale or colorless upon dilution with HCl. This indicates the presence of flavonoids in all five species.

($FeCl_3$) was added with 2–3 drops of 5% of the solution ($FeCl_3$). The appearance of blue or green coloration indicates that tannins are present in four (4) tree species, except the Balobo tree.

Tannins: from the prepared extract (1–2 mL) of the five tree species, ferric chloride. Saponins: from the prepared extract (1–2 mL) of the five tree species, add 10 mL of distilled water. The mixture was vigorously stirred for 15–30 s. Persistent foam that lasted for 15–30 s was observed in the four (4) tree species except for the Balobo tree.

Cytotoxicity Analysis

The following are procedures in the analysis of the cytotoxicity of the selected edible fruit and ethnomedicinal trees.

Crude Extraction via Methanol Cytotoxicity Analysis

Whole leaves were washed and air-dried until the texture was crisp (3–7 days). Samples were then macerated using a blender, weighed at 200 g, and then fully soaked in > 99% methanol for 72 h. The resulting extract was filtered through a No. 2 Whatman filter to remove leaf debris. 100 mL filtrate was then concentrated using rotary evaporation until the volume was around 25–30 mL, and then oven-dried at 40 °C to completely dry any remaining solvent. Lastly, the dried extracts were dissolved in DMSo solvent at 10 mg/mL in preparation for the MTT Assay.

MTT Cytotoxicity Assay

The MTT cytotoxicity assay was performed with minor modifications [14]. MCF-7 breast cancer cells were cultured in Minimum Essential Medium supplemented with 10% fetal bovine serum (FBS), 1% antibiotic-antimycotic, and 1mg/ml insulin, and seeded at 8000 cells per well in sterile 96-well microtiter plates. Plates were incubated overnight in a humidified incubator at 37 °C and 5% CO_2 to allow for cell attachment.

Eight two-fold dilutions of the sample were used as treatment, starting from 100 µg/mL down to 0.78125 µg/mL. Doxorubicin served as a positive control, while DMSO served as a negative control. After overnight attachment, cells were treated with the prepared concentrations of samples and controls and were again incubated for 72 hours at 37 °C and 5% CO_2.

After 72-hour incubation, 0.5 mg/mL of 3 (4,5-dimethylethythiazol-2-yl)-2,5-diphenylthrazolium bromide (MTT) dye was added. The MTT-treated cells were incubated at 37 °C and 5% CO_2 for 3 h. After this, DMSO was used to dissolve the metabolized formazan crystals formed through the reduction of the MTT dye. Absorbances were read at 570 nm wavelength (OD570) using a spectrophotometric microplate reader. Percent inhibition was computed through the following formula:

$$\% \text{ Inhibition} = \frac{[\text{0D570 (negative control)} - \text{0D570 (sample)}]}{\text{0D570 (negative control) x 100}}$$

The Inhibition Concentration at 50% (IC50) was computed using GraphPad Prism 10 via non-linear regression (curve fit) for Absolute IC50, wherein X = log (concentration) and Y = % Inhibition (with top value (Y) = 100% inhibition and baseline = 0% [15].

2.2.3. On the Identification of Threats

A Key Informant Interview was undertaken to determine the threats faced by the selected edible and ethnomedicinal trees. There were 20 local experts and five (5) from the Department of Environmental and Natural Resources Office (DENR) of the province.

Questions to identify threats to the five tree species included observation-, consequence-, and fact-based inquiries. Respondents were asked about general threats and specific follow-ups on issues such as climate-related extreme weather, pests and diseases, forest product harvesting, and forest clearing. The results were considered as the basis for protection, conservation, and sustainable management of the trees considered in this study.

2.2.4. Data Analysis

Data analysis used both qualitative and quantitative approaches. An analysis of the chemical content of cytotoxicity was presented using a quantitative method. Phytochemical content was analysed qualitatively. While describing the forms and structures of trees, as well as the threats, the presentation used a qualitative method.

3. Results and Discussions

3.1. Morphological Characteristics and Conservation Status of Selected Edible Fruits and Ethnomedicinal Trees

There were five (5) tree species documented that belonged to the following families: Malvaceae of Balobo *(Diplodiscus paniculatus Turez.)*; Moraceae of Baleteng-kapalan *(Ficus crassiramae Miq.)*; Myrtaceae of Malatampui-haba *(Syzygium longipedicellatum (Merr) Merr);* Dilleniaceae of Katmon-kalabaw (Dillenia reifferscheidia); and Actinidiaceae of Soybo *(Saurauia philippinensis Merr.)*. These edible and ethnomedicinal trees are thriving in the different municipalities of the province of Apayao. Angagan, J. 2009, identified wild food and ethnomedicinal plants used by indigenous communities of Apayao, more or less 50 species of medicinal plants, with various uses such as fiber extraction and swidden agriculture.

The morphological features of selected edible and ethnomedicinal trees revealed that variations in forms and structures in tree parts (tree size, leaves, barks, flowers, fruits, and seeds) are evident, as presented below (**Tables 1–5** and **Figures 2–6**). Balobo *(Diplodiscus paniculatus Turez.)* is an important tree species with unique morphological features such as its flaky bark, young leaves with a purplish tinge, clustered and fragrant flowers, and scaly fruits. Baleteng-kapalan *(Ficus crassiramae Miq.)* has distinct morphological features like an umbrella-shaped crown, leathery leaf blades, and fruits that are yellow to purple at maturity. Malatampui-haba (*Syzygium longipedicellatum (Merr) Merr)* exhibits salient characteristics small tree with fruits known as fleshy and edible. Katmon-kalabaw *(Dillenia reifferscheidia)* has notable features, are leathery leaves and flowers with large sepals enclosing the fruit; lastly, Soybo *(Saurauia philippinensis Merr.)* has remarkable features, including a tall tree with serrately toothed leaves, and the fruit is considered a berry. Morphological characterization remains as the fundamental basis for identifying and classifying species, with traits such as leaf shape, flower structure, fruit characteristics, and bark features providing reliable criteria for distinguishing trees in natural habitats [16]. These tree species are found within the primary and secondary forest with a forest type of lowland Dipterocarp forest. Balangcod & Balangcod reported that lowland dipterocarp forests are dominated by Dipterocarpaceae species, supporting the growth of numerous ethnomedicinal trees due to their high species diversity and suitable environmental conditions.

Table 1. Morphological Description and Conservation Status of Bagobo.

Local Name	Bagobo
Common Name	Balobo
Scientific Name	*Diplodiscus paniculatus* Turez
Family Name	Malvaceae
Location	Marag, Luna, Apayao
Coordinates	X- 18°19’56” Y- 121°17’10”
Description	Balobo is a medium-sized tree with an irregular trunk and buttressed base. Its bark is brown, flaky, and fibrous. Its leaves are simple, alternate, and chartaceous. Young leaves have a purplish tinge. Its flowers are yellowish-white, fragrant, and short-pedicelled. Its fruits are brown, scaly, somewhat ridged longitudinally, and sub-globosely hard. (Sources: ASC Forestry Faculty validated by NVSU-CFERM Faculty and RISE Volume 30. No. 1-ERDB)
Habitat	The species can be found in primary and secondary forests at low to medium altitudes, often on flat land, and seldom on sloping areas.
Phenology	It blooms and ripens from May to July.
Uses	Wood can be ideal for toothpicks, tool handles, packing boxes for pulp and paper, construction work, and charcoal. The fruits are edible once cooked. Helps reduce inflammation due to the flavonoid content
Propagation	Seeds can propagate the species. For asexual propagation, cleft grafting and marcotting can be used.
Timber Classification	Lesser Used Species
Conservation Status	Vulnerable (IUCN Red List of Threatened Species)

Table 2. Morphological Description and Conservation Status of Baleteng-kapalan.

Local Name	Balitlit
Common Name	Baleteng-kapalan
Scientific Name	*Ficus crassiramae* Miq
Family Name	Moraceae
Location	Eleazar, Calanasan, Apayao
Coordinates	X- 18°16’58” Y- 121°4’14”
Description	It is a strangling fig with a broad and spreading crown. The crown is broad and spreading, in an umbrella shape. The foliage is spirally arranged, and stalked leaves have leathery leaf blades that are oblong to narrowly drop-shaped. The fruits are in pairs at the leaf axils, yellow to purple at maturity. (Sources: ASC Forestry Faculty validated by NVSU-CFERM Faculty and http://www.stuartxchange.org/BaletengKapalan)

Table 2. *Cont.*

Habitat	Terrestrial (Primary Rainforest, Secondary Rainforest, Coastal Forest)
Phenology	Fruiting season: June–August
Uses	Roots, bark, and leaves are applied to snake bites. For anti-inflammatory, antimicrobial, and antioxidant activities due to the presence of flavonoids, tannins, and saponins.
Propagation	It can be propagated by seed, stem cutting, or air-layering.
Timber Classification	Lesser Used Species
Conservation Status	Least Concern Species (IUCN Red List of Threatened Species)

Table 3. Morphological Description and Conservation Status of Malatampui-haba.

Local Name	Bayabas ti Ilocano
Common Name	Malatampui-haba
Scientific Name	*Syzygium longipedicellatum* (Merr) Merr
Family Name	Myrtaceae
Location	Poblacion, Kabugao, Apayao
Coordinates	X- 17°57'13" Y- 121°12'47"
Description	A small tree with broadly ovate, obtuse, strongly cordate, sessile leaves, and a much elongated, three-flowered, racemose inflorescence. Branches terete, glabrous, light gray. (Sources: ASC Forestry Faculty validated by NVSU-CFERM Faculty and Plants of the World Online).
Habitat	Tree in a lowland mixed dipterocarp forest.
Phenology	The flowering season for Bitok is from April to May, while the fruiting season extends from June to August.
Uses	Wood- used for light construction. The fruit may be consumed fresh for anti-inflammatory, antimicrobial, and antioxidant activities due to the presence of flavonoids, tannins, and saponins.
Propagation	By seed
Timber Classification	Lesser Used Species
Conservation Status	Least Concern Species (IUCN Red List of Threatened Species)

Table 4. Morphological Description and Conservation Status of Katmon-Kalabaw.

Local Name	Palaling Nuwang
Common Name	Katmon Kalabaw
Scientific Name	*Dillenia reifferscheidia* Naves
Family Name	Dilleniaceae
Location	Upper Maton, Pudtol, Apayao
Coordinates	X- 18°19'17" Y- 121°16'35"
Description	Katmon kalabaw is a tree reaching a height of 6 to 15 m, smooth or nearly so. Leaves are leathery, shining, ovate, elliptic, or oblong-ovate, 12 to 25 cm long, and coarsely toothed at the margins. Flowers are white, large, soft, fleshy, and green, 6 to 8 cm in diameter, with large fleshy sepals tightly enclosing the true fruit. (Sources: ASC Forestry Faculty validated by NVSU-CFERM Faculty and Plants of the World Online)
Habitat	Found primary forest at low and medium altitudes
Phenology	The flowering period lasts from June to October, while the fruiting season occurs from October to February.
Uses	Wood- suitable for construction work. The fruit may be consumed fresh for anti-inflammatory, antimicrobial, and antioxidant activities due to the presence of flavonoids, tannins, and saponins.
Propagation	By seed
Timber Classification	Lesser Used Species
Conservation Status	Threatened (IUCN Red List of Threatened Species)

Table 5. Morphological Description and Conservation Status of Soybo.

Local Name	Marinsipon
Common Name	Soybo
Scientific Name	*Saurauia philippinensis* Merr.
Family Name	Actinidiaceae
Location	Eleazar, Calanasan, Apayao
Coordinates	X- 18°15'8" Y- 121°3'42"
Description	Tree with spreading branches to 10 m tall. Leaves are simple, alternate, oblong, and serrately toothed toward an acuminate apex. Flowers are white, in long-pedunculate inflorescences in upper leaf axils. Fruit is a berry, compressed-globose.
Habitat	Inhabiting secondary tropical lowland evergreen rainforest at ca. 331 masl
Phenology	Flowering Season: June-July Fruiting Season: July–October
Uses	The fruit may be consumed fresh for anti-inflammatory, antimicrobial, and antioxidant activities due to the presence of flavonoids, tannins, and saponins.
Propagation	By seed
Timber Classification	Lesser Used Species
Conservation Status	Least Concern Species (IUCN Red List of Threatened Species)

Figure 2. Balobo. (**a**) Habit of mature tree; (**b**) Bark; (**c**) Phyllotaxy or leaf arrangement; (**d**) Flower; (**e**) Mature fruit.

Figure 3. Baleteng-kapalan. (**a**) Habit of a mature tree; (**b**) Bark; (**c**) Phyllotaxy or leaf arrangement; (**d**) Mature fruit.

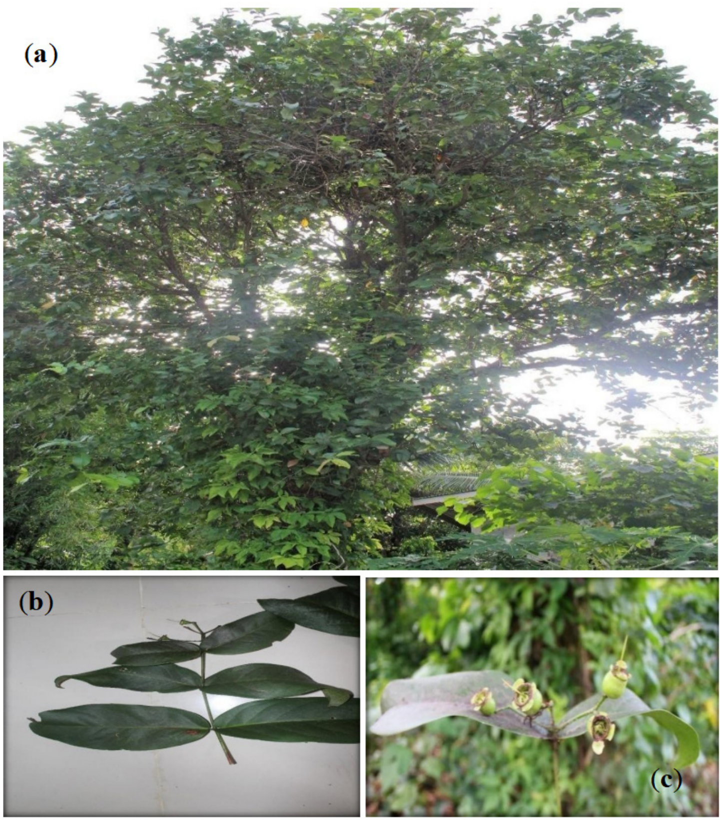

Figure 4. Malatampui-haba. (**a**) Habit of a mature tree; (**b**)Phyllotaxy or leaf arrangement; (**c**) Fruit.

Figure 5. Katmon kalabaw. (**a**) Habit of a mature tree. (**b**) Bark. (**c**) Phyllotaxy or leaf arrangement. (**d**) Mature fruit.

Figure 6. Soybo. (**a**) Habit of a mature tree; (**b**) Bark; (**c**) Phyllotaxy or leaf arrangement; (**d**) Flower; (**e**) Mature fruit.

In terms of the Phenology of the five (5) tree species, they exhibited different months of flowering and fruiting. Usually, they complete their flowering and fruiting once a year. Phenology provides knowledge on the schedule of flowering and fruiting, which helps determine the optimal period for harvesting medicinal plants to maximize their bioactive compounds. Moreover, propagating these tree species is through seed and asexual methods. Propagation of ethnomedicinal trees through seeds introduces genetic variation, which improves the ability to adapt and survive for the species composition to changing environmental conditions [17]. Regardless of its benefits, seed propagation may be affected by germination rates, seed dormancy, and environmental factors. On the other hand, an asexual method facilitates propagation technology, enabling plant production at scale, and the application of this approach in the preservation of endemic and endangered plant species would aid in the conservation of natural assets [18]. While it provides certain benefits, asexual propagation has insufficient genetic variation, resulting in cloned plants being more prone to diseases and environmental stress [19]. This method is applicable for species with low natural regeneration rates or those whose seeds exhibit dormancy or low viability, maintaining the level of abundance and genetic quality [20]. Chen (2016) claimed that asexual propagation is highly recommended for tree species facing extinction pressures through ex situ conservation programs for sustainable production and utilization.

Utilization of the five (5) tree species is for ethnomedicinal purposes, construction, and raw materials for pulp and paper, toothpicks, and tool handles. The ecological status of the selected edible and ethnomedicinal trees ranged from least concern, vulnerable, and threatened. Species classified as Least Concern generally show stable stability, resilient habitats, and are not so much affected by human activities, pests, diseases, or environmental factors. They contribute to ecosystem services such as carbon sequestration, soil stabilization, and habitat for other organisms. Vulnerable species are considered to be at high risk of extinction because of threats like habitat loss, overharvesting, pests, diseases, and climate change. Threatened species—classified as critically endangered, endangered, or vulnerable—are indicators of ecosystem health because their survival depends on intact habitats and functioning ecological processes [21]. Ecological assessments of trees contribute to conservation planning since ethnomedicinal species contribute to rural health care while simultaneously supporting conservation objectives, particularly within biosphere reserves and protected areas [22]. Thus, knowing the various roles and importance of trees highlights their ecological, economic, medicinal, and cultural importance, emphasizing the need for conservation and sustainable utilization, particularly for species with ethnomedicinal value and threatened ecological status.

The analysis employed in this section is qualitative-descriptive, emphasizing narrative description, observation, classification, and interpretation of ecological and ethnomedicinal characteristics.

3.2. Phytochemical Analysis of the Selected Edible and Ethnomedicinal Trees

Table 6 presents the phytochemical analysis of the selected edible and ethnomedicinal trees. It could be noted that the five (5) tree species possessed flavonoids, tannins, and saponins, except for Balobo, wherein tannins and saponins are absent. Flavonoids are a main class of secondary metabolites usually present in the leaves of many tree species. These compounds have an important role in protecting plants from environmental factors such as ultraviolet radiation, pathogens, and herbivores [23]. Leaf flavonoids are known for their antioxidant, anti-inflammatory, anticancer, and antimicrobial properties, making them significant in both alternative local medicine and pharmaceutical research [24]. In the context of food quality assurance, flavonoids contribute to food safety by preventing the development of harmful microorganisms and minimizing oxidative damage in food products [23]. Ulla 2020 claimed that it not only gives health benefits to consumers while also acting as a natural preservative, prolonging shelf-stability and safety of food preparations derived from leaves, fruits, or extracts.

Table 6. Phytochemical analysis of edible and ethnomedicinal trees.

Common Name	Parameter (Phytochemical Screening) Results
Balobo	With Flavonoids, No Tannins, and Saponins
Baleteng-kapalan	With Flavanoids, Tannins, and Saponins
Malatampui-haba	With Flavanoids, Tannins, and Saponins
Katmon Kalabaw	With Flavanoids, Tannins, and Saponins
Soybo	With Flavanoids, Tannins, and Saponins

Tannins represent the largest group of polyphenols. They are widely distributed in the bark of trees, insect galls, leaves, stems, and fruit [25]. Tannins were used as traditional medicine for their antimicrobial, anti-inflammatory, and astringent properties. For instance, the leaves of *Terminalia anogeissiana* are rich in gallotannins and are used for medicinal purposes in India [26]. Also, tannin contributes to food safety because of its antimicrobial and antioxidant contents. These compounds inhibit the growth of pathogenic microorganisms and lessen oxidative spoilage, thereby promoting the shelf life and safety of food products [27,28].

Saponins are a class of secondary metabolites that can be found in parts of trees, such as leaves, bark, and roots. They serve as protective compounds, preventing pathogens because of their bitter flavor and foaming ability. Saponins are known to have antimicrobial, anti-inflammatory, and anticancer properties, making them important in both traditional medicine and modern pharmacology (Sparg et al., 2004). Examples of saponins present in Philippine trees include *Syzygium polycephalum* (Lipoted tree) and *Garcinia binucao* (Binukao tree) [29]. These compounds can suppress the growth of pathogenic bacteria and fungi, reducing the risk of foodborne illnesses and spoilage [30].

In addition, certain phytochemicals from edible tree species enhance food quality by contributing to flavor, color, and preservation, while also providing protective health benefits [31]. Therefore, the presence of phytochemicals implies that the five tree species considered in this study have food safety and medicinal values that could contribute to the global market for herbal medicines.

Overall, these secondary metabolites provide various ecological and pharmacological roles, such as protective functions in ecosystems and medicinal value for humans. The ecological and economic importance of bioactive compounds provides a strong rationale for conservation. Protecting species with unique phytochemicals not only upholds ecological diversity but also ensures the long-term availability of natural resources for pharmaceutical and nutraceutical development [32,33]. Their presence promotes the conservation priority of species by exemplifying distinctive chemical properties that enhance ecosystem adaptability, socio-cultural significance, and potential economic prospects through sustainable management. Research has shown that characterizing and recording these compounds can support strategic conservation planning, direct habitat management efforts, and support responsible harvesting methods, thereby ensuring the long-term survival of ecologically and chemically significant species [34–37] that contribute to local and regional economies by providing employment, income, and trade opportunities through sustainable harvesting and commercialization [38].

Hence, this provides an avenue for bioeconomy development, promoting both economic growth and conservation of ecologically important species.

The data analysis presented in this section is qualitative-descriptive with interpretive insights. It does not involve statistical calculations or quantitative comparisons; instead, it relies on documenting, explaining, and interpreting observed chemical traits and their ecological, medicinal, and economic relevance.

3.3. Cytotoxicity Analysis

The nature of data analysis in this paragraph is primarily quantitative-descriptive with interpretive insights.

Cytotoxicity testing is important to determine the safety levels of tree extracts and ensure that traditional or commercial herbal preparations are not harmful at therapeutic doses. The cytotoxic properties of tree leaves have gained significant interest due to their potential in cancer therapy.

Table 7 shows the result of cytotoxicity analysis for Baleteng-kapalan, which exhibited a highly toxic interpretation with a cell line tested, MCF-7 breast cancer, and an IC50 value of 0.8453 µg/mL. According to the National Cancer Institute (NCI) criteria, crude extracts with IC_{50} values ≤ 20 µg/mL are considered highly cytotoxic, while extracts with IC_{50} values between 20 and 100 µg/mL are classified as moderately active [39]. This means that the strong cytotoxicity of Balerteng-kapalan for breast cancer cells serves as a source of bioactive compounds for cancer cell therapy. Balobo, Katmon-kalabaw, and Malatampoi-haba exemplified a moderate cytotoxicity, 50.32 ug/mL, 62.10 ug/mL, and 89.91 ug/mL, respectively. Moderate cytotoxicity refers to the ability of a leaf extract or its bioactive compounds to inhibit cancer cell growth to a substantial but not maximal extent. Only the Soybo tree exhibited weak cytotoxicity. If a plant extract has IC_{50} > 100 µg/mL against MCF-7 cells, it is generally interpreted as weakly cytotoxic [40]. Weakly cytotoxic extracts may still contain bioactive compounds, but they are less effective than moderately or highly cytotoxic extracts. They may be beneficial in integration with other alternative therapies, or as an initial step for further isolation and concentration of active compounds. The presence of compounds in leaves of the five (5) tree species could be formulated into natural chemotherapeutic agents or serve as a supplement to existing breast cancer therapies.

Table 7. Cytotoxicity analysis of edible and ethnomedicinal trees.

Species	Cell Line/s Tested	IC50 Value (ug/mL)	Interpretation
Balobo	MCF-7 breast cancer	50.32	Moderately cytotoxic
Soybo	MCF-7 breast cancer	532.0	Weak to non-cytotoxic
Katmon Kalabaw	MCF-7 breast cancer	62.10	Moderately cytotoxic
Baleteng-kapalan	MCF-7 breast cancer	0.8453	Highly cytotoxic
Malatampui-haba	MCF-7 breast cancer	89.91	Moderately cytotoxic

This highlights the importance of protecting and conserving these tree species and further studying their phytochemicals and mechanisms of action for drug discovery. Evaluating the cytotoxicity of extracts from edible and ethnomedicinal plants helps assure that consumption does not pose harmful effects to human cells, thereby contributing to food safety and quality control [14]. With food products derived from ethnomedicinal trees, cytotoxicity assays guide the appropriate concentration and utilization of plant extracts, reducing health risks while maintaining functional benefits.

Moreover, studying the cytotoxic attributes of ethnomedicinal trees shows a strong prospect for economic growth by discovering bioactive compounds with pharmaceutical applications. Different plant-derived compounds have been observed to exhibit selective cytotoxicity against cancer cell lines, showcasing their significance as sources for anticancer drug development. Studies have demonstrated that natural compounds from medicinal plants and trees show significant antiproliferative, emphasizing their relevance in drug discovery and the advancement of pharmaceutical research [41]. The product development and marketing of these compounds can promote the biotechnology and pharmaceutical sectors, generate employment, and support local economies through sustainable utilization of natural resources. Incorporating traditional ethnomedicinal knowledge with scientific research not only advances health services but also contributes to economic development by creating commercially enhanced products from plant-derived therapeutics.

3.4. Threats to Selected Edible and Ethnomedicinal Trees

Based on the Key Informant Interviews, the respondents were probed in depth to gather their observations on the threats faced by these tree species and other forest trees they consider important. The observed threats to the survival of these trees include extreme weather events triggered by climate change, such as droughts and typhoons, and anthropogenic activities like illegal gathering of forest products and forest fire caused by clearing of forest or kaingin making.

The province of Apayao, situated in the Cordillera Region, wherein typhoons entering the Philippines through northern Luzon pass near or directly affect Apayao. In

2023, Apayao endured drought conditions and was severely affected by Super Typhoon Egay, which caused approximately ₱546.89 million in damages to agriculture and forestry, and by Super Typhoon Ompong in 2018, which inflicted around ₱488 million in similar losses. More recently, in November 2024, the province was placed under a state of calamity after Typhoon Marce struck, bringing strong winds and heavy rains that devastated properties, infrastructure, and crops—including corn, palay, banana, cassava, coconut, vegetables, and fruit trees—with damages amounting to about ₱1.22 billion [42,43].

Several studies suggest that extreme weather events brought by climate change may reduce suitable habitats for many key medicinal species, potentially compromising ecosystem functions and the availability of natural medicines for local communities [44]. The survival and habitat of these edible and medicinal tree species are affected by climate variables such as annual average rainfall, soil pH, and yearly average temperature. Alterations in temperature, rainfall, and precipitation associated with climate change will pose risks to the survival of these species [45]. Rising temperatures accelerate organic matter decomposition, alter nutrient cycling, and influence microbial communities, which can affect the soil's capacity to support plant life [46]. In addition, it alters their distribution, life cycles, and the synthesis of secondary metabolites [47].

Instances of apprehension related to the gathering of forest products have been observed in the forest areas of the province. Harvesting of non-timber forest products (NTFPs) can alter forest structure, composition, and regeneration, potentially threatening the sustainability of ethnomedicinal species [48]. Illegal harvesting leads to destructive practices such as clear-cutting or uprooting trees, leading to soil erosion, loss of soil fertility, and disruption of the forest ecosystem, which negatively affects other plant and animal species [49], resulting in the decline of genetic diversity, which reduces the resilience of populations to environmental stresses, diseases, and climate change.

In addition, observed pest and disease infestations have manifested through necrotic symptoms such as yellowing of leaves, shot holes, and spots. Climate change cause as a major factor that exacerbates pests and diseases, affecting both ecological stability and the sustainable utilization of ethnomedicinal tree species. For instance, warmer and wetter conditions can intensify insect life cycles, increase reproduction rates, and widen their geographic range, leading to unaffected areas susceptible to infestations. Also, changes in temperature and humidity can lower tree resistance and increase fungal and bacterial diseases. These alterations compromise the health, productivity, and survival of ethnomedicinal trees, which may affect the availability of bioactive compounds essential for traditional medicine and local economies [50].

Forest fires associated with land-clearing activities have also been reported, including a recent occurrence in a boundary area between two municipalities within the province. Forest clearing is usually done due to kaingin making, which is a source of livelihood for the upland dwellers. The clearing of trees and other vegetation decreases the humidity and elevates temperatures, resulting in drier conditions that are more favorable to ignition and accelerate fire occurrence. Forest fires can have a devastating impact on forest vertebrates and invertebrates, loss of habitats, destruction of food trees, and shifts in species composition, all of which threaten overall biodiversity and forest recovery [51]. Strong forest fires can severely alter soil microbiomes, resulting in changes in the richness and composition of ethnomedicinal plant species in affected forest areas. It also damages the stem tissues of young trees and seedlings, leading to the death of roots, hindering the regeneration of ethnomedicinal tree species [52]. The growing threat of emerging plant pathogens and insect pests to tree health worldwide stresses the need for integrated pest management strategies [53].

These combined pressures underscore the need for integrated conservation strategies. Approaching threats separately does not effectively mitigate their impacts. Sustainable management entails addressing concurrently the climate adaptation, habitat restoration, protection from overexploitation, and pollution mitigation to maintain ecosystem services and conserve biodiversity [54]. This conservation effort is significant to prevent edible and ethnomedicinal trees from advancing toward higher risk categories of ecological status cited in the IUCN Red List of Threatened Species. Achieving sustainable management of forest resources entails policies that regulate resource use, promote conservation and protection, support climate resilience, engage stakeholders, and ensure monitoring and enforcement. Thus, sustainable management of resources and policy development are interdependent; both ensure that forests continue to provide ecological, economic, and social services for present and future generations.

The nature of data analysis in this section is primarily qualitative-descriptive with interpretive elements.

3.5. Policy Recommendations for Protection and Conservation of the Selected Edible and Ethnomedicinal Trees

The need to ensure the reliable supply of quality herbal medicines emphasizes the concurrent identification of necessary measures to efficiently manage local natural resources from which herbal plants are derived. Thus, the policy recommendations for this project are the following:

3.5.1. Sustainable Environmental Resource Management—In the Context of Utilization

To guarantee the sustainable utilization of ethnomedicinal trees, the local government should enforce regulations on their harvesting for fuelwood, charcoal production, and construction purposes. This can be done by developing clear harvesting guidelines that sustain the survival of these species while supporting responsible and sustainable use of ethnomedicinal tree resources. Also, at the local level, the reproduction of these species through ex situ conservation should be incorporated into resource management plans.

3.5.2. Climate Resilience Strategy—In the Context of Conservation

Ethnomedicinal trees, as native species, should be prioritized in propagation and reforestation programs. Encouraging their planting and maintenance can strengthen local ecosystems, enhance biodiversity, and improve resilience to climate-related disturbances, ensuring long-term ecological and community benefits.

3.5.3. Adoption of Policy Recommendations

The Municipal Local Government of Flora, Apayao, adopted the policy recommended by the author through Municipal Ordinance Number 03-2025. An ordinance for the protection and conservation of ethnomedicinal trees in the municipality of Flora, Apayao. The said ordinance was endorsed by the Legislative Body and approved by the Office of the Mayor of MLGU Flora, Apayao.

4. Conclusions

Five edible and ethnomedicinal tree species were characterized, each with notable morphological features that help in tree identification. Their phenological pattern and propagation methods are important in the context of genetic diversity and reproduction for conservation and sustainability. In addition, the five tree species contain key bioactive compounds that aid plant adaptability against environmental stress and offer essential benefits, such as their role in food safety, preservation, and pharmacology, which are important to human health and economic opportunities. Finally, the identification of ecological threats provides a vital basis for developing targeted protection and conservation strategies. Sustaining these species is not only essential for biodiversity preservation but also for maintaining their ecological and medicinal provisioning services that benefit both local communities, traditional and modern medicine systems.

Recommendations

1. Further study on the phenology of the five (5) tree species;
2. Study of phytochemical and cytotoxicity contents of other parts of the tree species aside from their leaves; and
3. Present the policy brief to the other MLGUs of Apayao for the adoption of policies on the protection and conservation of the edible and ethnomedicinal trees to reduce threats to these tree species

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Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not Applicable.

Data Availability Statement

All data generated in the course of this study are available in this article.

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Conflicts of Interest

The author declares no conflicts of interest.

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