Chapter

Biodiversity of Fabaceae in the Brazilian Amazon and Its Timber Potential for the Future

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Abstract

The vegetation of Neotropical forest of Amazonian region is one representative part of global biodiversity in Fabaceae, with numerous species for wood production, oil, fruits, or other forests products or same ecosystemic services for agricultural production. This chapter gathers information on the biodiversity of Fabaceae of the Amazon, highlighting the timber species in the set of existing plant genetic resources. Systematic information emphasizes the importance of basic forestry information, and potential for cultivation in agroecosystems or for management, forestry and reforestation. The product of the highest economic value of the Fabaceae of the Brazilian Amazon is wood, which is sold in local, regional markets and exported to other countries. Also noteworthy is the ability acquired evolutionarily by many Fabaceae: the symbiotic fixation of N_2 with soil bacteria of the Rhizobia group, character particularly important for soil recuperation or reforestation.

Keywords: biodiversity, Fabaceae, Amazon, forestry, timber

1. Introduction

The Amazon rainforest is known as one of the hot spots of biodiversity in the world, and has, in its geographical area, numerous zones of detachable biological variety, centers of diversity, with incalculable stock of genetic resources for current and future use. Recent estimates of plant biodiversity in the Amazon indicate that of the 270,000 terrestrial plant species, 32,000 are present in Brazilian biomes (11.8% of global biodiversity) and, of these, ± 14,000 species in the Brazilian Amazon representing 5.2% of global biodiversity [1].

Territorially the continental Amazon occupies 50% of the surface of South America, distributed geographically in nine countries: Bolivia, Colombia, Ecuador, Guyana, French Guiana, Peru, Suriname, Venezuela and Brazil (**Figure 1**). In Brazil, the ecological domain of the Amazon biome has 3.68 million km^2, which added to the ecotone zones with the Caatinga and Cerrado biomes total 4.24 million km^2, which corresponds to 49% of the Brazilian territory [2].

The need for natural wood managed or reforestation to meet local and global market demand is a consensus among reforestation and, in the future, natural and

Figure 1.
Geographical distribution of the Amazon biome in northern South America. Fonte: https://news.files.bbci.co.uk/include/vjamericas/304-countries-amazon-rainforest/portuguese/app/embed.

cultivated forests will have great economic and social importance, in addition to contributing to carbon sequestration and global climate stability. Among the natural riches of the Amazon, its timber potential stands out, which are estimated at tens of millions of m^3, and which can, in unprotected areas, be rationally exploited with sustainable forest management practices.

2. Biodiversity of Fabaceae in the Amazon region

In the Amazon, the Italian botanist Adolpho Ducke (1876–1959) pioneered the diversity of the Fabaceae family. In 1925, Ducke published "The legumes of the state of Pará," and, with the progress of his research in the region, in 1949, presented the basic treatise: "The Legumes of the Brazilian Amazon," relating 867 species of Fabaceae [3, 4]. Subsequently, the botany Marlene Freitas da Silva (1937–2005) related the Fabaceae of the Brazilian Amazon with estimates of 1241 species distributed in its three subfamilies: Caesalpinioideae, Mimosoideae and Faboideae [5].

Standing out in the tropical forest in number of species and frequency in the listing of the main timbers exported from the Amazon region, the trees of the Fabaceae family it's adapted in the different ecological environments of this biome. In the world, the geographical distribution of Fabaceae stands out in tropical and subtropical regions and numerically represents the second largest family of Magnoliopsid plants (surpassed by Orchidaceous), estimating global biodiversity in 19,325 species classified in 727 botanical genera [6]. In the different Brazilian biomes, which include the Amazon, Cerrado, Caatinga, Atlantic Forest, Pantanal and Pampas, the diversity of Fabaceae is currently estimated at 2964 species (1458 endemic), 53 subspecies (16 endemic) and 731 varieties (419 endemic), sheltered in 210 genera [7].

The Fabaceae of the Amazon are represented in arboreal, shrubby, liana, herbaceous, underwater and aquatic forms. This detachable plasticity of growing habits includes trees of different sizes, occupying the niches of understory to the upper canopy, but also diversified in shrubs, lianas and herbs. In Fabaceae phylogeny, the tree component forms the most primitive group with tropical origin and the most evolved herbaceous group, whose evolutionary differentiation occurred mainly in subtropical zones and even in temperate zones [8].

The family Fabaceae (Leguminosae) is one of the most natural of the Division Magnoliophyte and belongs to the Fabales order. As for phylogeny, Fabaceae are divided into three subfamilies: Caesalpinioideae, Mimosoideae and Faboideae and each has branches consisting of classification tribes. In each subfamily, the distinctions between genera and species are related to floral morphology. Thus, the main differential characteristics between the three subfamilies are [9]:

Caesalpinioideae: These are trees, shrubs and rare herbaceous or scanning plants, distributed mainly in tropical and subtropical regions, with ±180 genera and between 2500 and 3000 species. The leaves are usually pined or sometimes pecked. The flowers are slightly zygomorphic, and the side petals (wings) cover the banner on the button. The stamens are numbered 10 or less (free or monoadelphal). It is considered the most primitive subfamily within the Fabaceae.

Mimosoideae: They are trees, shrubs, woody vines, with few perennial herbaceous, in tropical and subtropical regions, with approximately 56 genera and ± 3000 species. The leaves are usually bipinated, with glands in the raque. The petiole usually presents pulvino and the presence of thorns is common, in those species differentiated in the dry environment, and these may originate from stipulations or occur along the branches. The flowers are regular or actinomorphs, androgynous or unisexual, with valve petals on the bud, with 10 stamens or more. In evolutionary terms, the species of this subfamily are positioned between the Caesalpinioideae and Faboideae.

Faboideae: Trees, shrubs and mainly annual or perennial herbs, distributed in temperate, tropical and subtropical zones, with 400–500 or more genera and > 10,000 species. The leaves are usually pined, but sometimes simple unifolioladas or trifolioladas. The flowers are hermaphrodite, typically zygomorphic, with side petals (wings) covered by the banner, on the button; 10 theses, usually diadelfs (9 + 1), but sometimes monoadelphal or free. The species of this subfamily, especially herbaceous ones, are considered more evolved among the Fabaceae.

The differentiation of species in subfamilies is mainly made by describing their floral morphology (**Figure 2**). Caesalpinioideae species have flowers in ascending pendulums, with five petals and 10 free stamens, e.g. *Aldina heterophylla*, *Campsiandra laurifolia* and *Senna multijuga*. Mimosoideae has flowers consisting of multiple and numerous stamens, defining a particular floral morphology in the set of Fabaceae, e.g. *Hydrochorea marginata*, *Inga cinnamomea* and *Parkia igneiflora*. The Faboideae, the most numerous group, have flowers with five petals and 10 stamens united at the base, or nine united stamens and one free, for example. *Clitoria fairchildiana* and *Dipteryx odorata*.

The most accepted evolutionary theory for the differentiation of Fabaceae attributes the origin of the family in the Mesosolic era, in the Late Cretaceous period, ±97 million years ago [10]. In the Amazon the genus *Hymenaea* (Caesalpinioideae) was researched with an evolutionary and ecological perspective, evidencing the African origin of neotropical species, possibly by migration across the Atlantic occurred at the beginning of the Tertiary (lower Paleocene), when the continents were closer and the tropical rain forest had a larger geographical distribution than the current one [11].

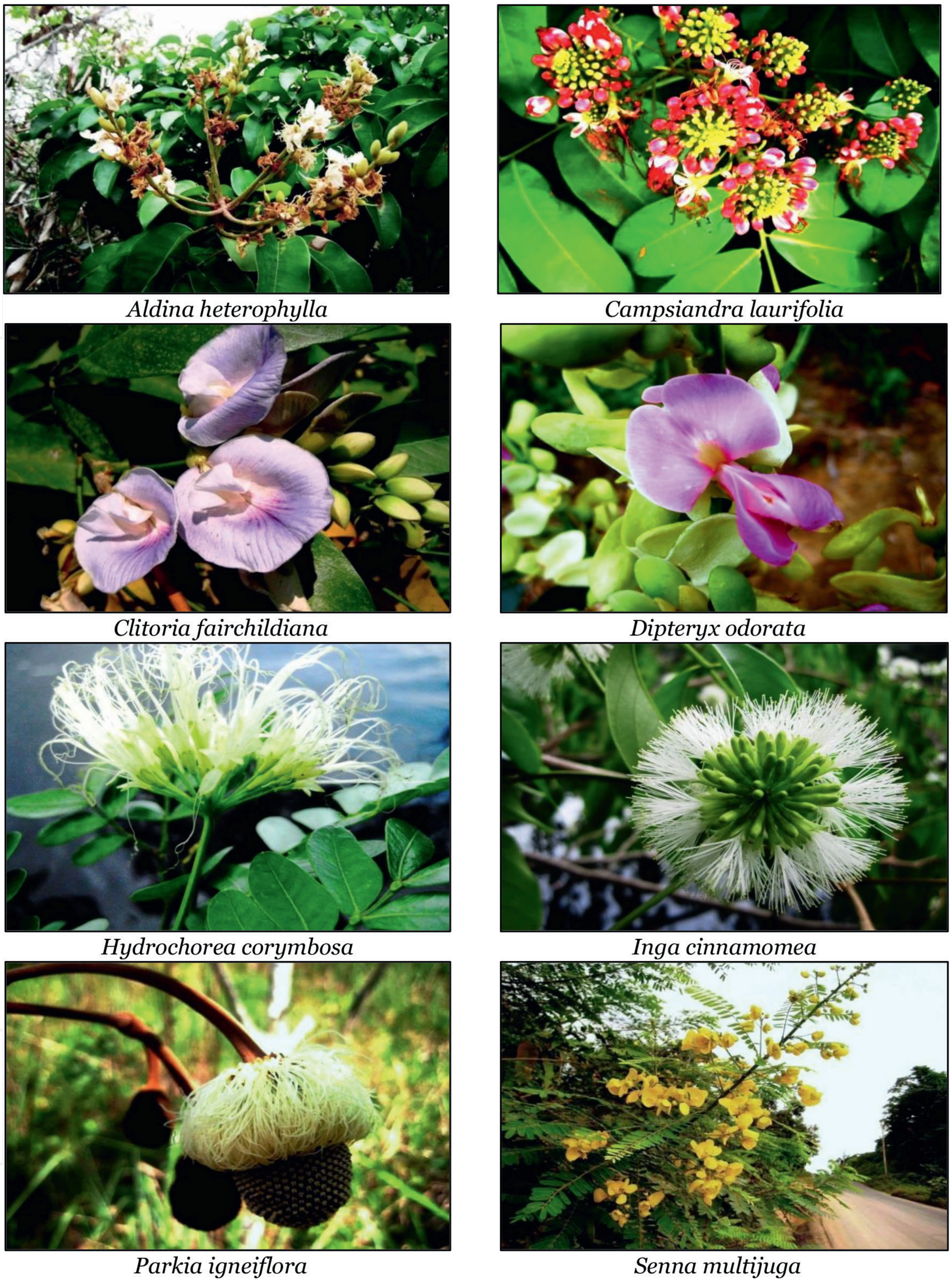

Figure 2.
Floral morphology of tree species of Fabaceae from the Amazon region of woody habit and wood interest. Photos: Souza LAG.

In primitive terms, the subfamily Caesalpinioideae originated the other ones and it is currently considered that the representatives of Faboideae form a more evolved group within the family, with 441 genera and ± 12,300 species with worldwide geographical distribution [8]. Considering phylogeny, the primitive Fabaceae have tropical origin and almost exclusively arboreal growth habit [12]. In fact, 95% of

Caesalpinioideae and Mimosoideae are woody species, frequent and abundant in tropical forests, as well as in the Brazilian Amazon.

3. Timber importance of Fabaceae of the Amazon

In Brazil, Fabaceae are classified into 210 genera, 160 of them represented in the Amazon [7]. In this geographical area, the biological diversity of Fabaceae is higher for tree and/or woody habit species (98 genera - 61.2% of the total) (**Table 1**). In ten of the genera listed (6.2% of the total), there are similar species with mixed growth habits, because they harbor tree plants, but also of a gaping, non-woody, shrubby and herbaceous habit. In 32.6% of the genera present in the region, there are no species with tree or woody growth.

The physiognomy of the rainforest is a mosaic of different landscapes that, in the Amazon, include the meadows and peasants, forests and lowland fields, seasonal igapós, streams, tidal forests, land fields, dense forests of soil no hydromorphic, dry or deciduous forests, transition forests, open forests of palm trees, vine forests and bamboo forests [13]. In these different physiognomies the richness in Fabaceae is numerically well represented and documented in floristic and phytosociological surveys already performed.

Although the number of woody genera is almost twice as high as non-woody ones, there is a lot of variation in the intraspecific number. The most representative woody genera are *Inga*, with 93 species, *Swartzia* with 80 and *Tachigali* with 44 species. In *Mimosa*, a genus that has mixed habit species, there are 36 species. In the flora of Brazil, some genera of Fabaceae are unique to the Amazon, among them *Eperua* and *Cynometra* (with 12 species each), *Aldina* (10 species), *Elizabetha* (9), *Crudia* and *Campsiandra* (6), *Alexa* (5), *Taralea* and *Heterostemon* (4), *Samanea*, *Hydrochorea* and *Clathrotropis* (3) and *Vouacapoua* and *Cenostigma* (two species) (Lima, 2010). There are also many monotypic genera, where some species such as *Cedrelinga cateniiformis* and *Dinizia excelsa*, which produce wood of economic value and there are also numerous genera that are represented by a single taxon.

There are other genera of Fabaceae very well represented, with diversity in species greater in the Amazonian flora, but which also has similar species in Brazilian biomes. Among them are: *Macrolobium* (34 species in the Amazon), *Ormosia* (23), *Dimorphandra* (19), *Abarema* and *Parkia* (16), *Peltogyne* (15), *Andira* (13), *Hymenolobium* (12), *Diplotropis* (9), *Dipteryx* (8), *Albizia*, *Erythrina* and *Hymenaea* (7), *Enterolobium*, *Vatairea* and *Platymiscium* (6), *Martiodendron* (3) and *Bowdichia* (2 species) [7].

Fabaceae trees of wood importance grow in native forests in economically unexplored areas and also in those altered by regional development. The size of the trees, preferred environment, trunk diameter and wood volume are diversified, as well as their technological properties and market value. In wood, there is a wide variety of coloration, density, texture, resistance to curving and other technological properties, suggesting multiple forms of utilization. For the species with the highest market value, there is an advance in the knowledge of the technological properties of wood supporting quality indicators that expand its potential for use.

In the identification of wood species in field conditions, to help identify the trees, the timber collector and parabotanists observe the morphological characteristics of the trunk, such as shape, color and texture of the bark and wood, presence or not of latex or resin and characteristic smell after small cut [14]. It is not always possible to

Growing habit	Genera of Fabaceae of the Amazon
Woody (trees)	*Abarema*, *Albizia*, *Aldina*, *Alexa*, *Amburana*, *Anadenanthera*, *Andira*, *Androcalymma*, *Apuleia*, *Ateleia*, *Barnebydendron*, *Batesia*, *Bocoa*, *Bowdichia*, *Brownea*, *Browneopsis*, *Caesalpinia*, *Calliandra*, *Campsiandra*, *Cassia*, *Cedrelinga*, *Cenostigma*, *Centrolobium*, *Chloroleucon*, *Clathrotropis*, *Cojoba*, *Copaifera*, *Crudia*, *Cyclolobium*, *Cynometra*, *Dialium*, *Dicorynia*, *Dimorphandra*, *Dinizia*, *Diplotropis*, *Dipteryx*, *Diptychandra*, *Dussia*, *Elizabetha*, *Enterolobium*, *Eperua*, *Erythrina*, *Etaballia*, *Guianodendron*, *Guilandina*, *Heterostemon*, *Hydrochorea*, *Hymenaea*, *Hymenolobium*, *Inga*, *Jacqueshuberia*, *Lecointea*, *Leptolobium*, *Leucaena*, *Macrolobium*, *Martiodendron*, *Monopteryx*, *Mora*, *Myrocarpus*, *Myroxylon*, *Ormosia*, *Paloue*, *Paloveopsis*, *Panurea*, *Paramachaerium*, *Parkia*, *Peltogyne*, *Pentaclethra*, *Petaladenium*, *Pithecellobium*, *Plathycyamus*, *Plathymenia*, *Platymiscium*, *Platypodium*, *Poecilanthe*, *Poeppigia*, *Poincianella*, *Pseudopiptadenia*, *Pterocarpus*, *Pterogyne*, *Recordoxylon*, *Samanea*, *Schizolobium*, *Stryphnodendron*, *Swartzia*, *Tachigali*, *Tamarindus*, *Taralea*, *Tipuana*, *Trischidium*, *Ulenthus*, *Vachellia*, *Vatairea*, *Vataireopsis*, *Vouacapoua*, *Zapoteca*, *Zollernia* e *Zygia.* (*n* = 98)
Mixed (woody and non-woody)	*Bauhinia*, *Chamaecrista*, *Clitoria*, *Dalbergia*, *Lonchocarpus*, *Machaerium*, *Mimosa*, *Piptadenia*, *Senegalia* e *Senna.* (*n* = 10)
Non-woody (shrubs, herbaceous and lianas)	*Abrus*, *Aeschynomene*, *Amphiodon*, *Arachis*, *Barbieria*, *Cajanus*, *Calopogonium*, *Camptosema*, *Canavalia*, *Candolleodendron*, *Centrosema*, *Chaetocalyx*, *Cleobulia*, *Collaea*, *Coursetia*, *Cratylia*, *Crotalaria*, *Cymbosema*, *Deguelia*, *Derris*, *Desmodium*, *Dicymbe*, *Dioclea*, *Discolobium*, *Entada*, *Eriosema*, *Exostyles*, *Fissicalyx*, *Galactia*, Harpalyce, *Indigofera*, *Macroptilium*, *Macrosamanea*, *Milletia*, *Mucuna*, *Neptunia*, *Nissolia*, *Pachyrhizus*, *Periandra*, *Phanera*, *Phaseolus*, *Psophocarpus*, *Pueraria*, *Rhynchosia*, *Sesbania*, *Sommeringia*, *Sophora*, *Stylosanthes*, Tephrosia, *Teramnus*, *Vigna* e *Zornia*. (*n* = 52)

Source: [7], adapted.

Table 1.
Diversity and classification regarding the habit of growth for 160 Amazonian genera of Fabaceae, regarding the growth habit of the species.

access the canopy of the plant when it develops in the upper canopy of the forest. Some characteristics of the trunk of amazon wood species are illustrated in **Figure 3**. Field identification recognizes the individual at the family, gender or even species level, and may be more accurate with sampling canopy, leaves and/or flowers or fruits. In addition to the knowledge of high-level botanical systematics, new technologies can help in the reliable recognition of species.

The use of wood of the species exploited by this potential is also quite varied, from civil and shipbuilding, carpentry, furniture, tacos, cutlery, adornment objects, and

Figure 3.
Aspect of the trunk and bark of Fabaceae species from the Amazon region of wood interest. Photos: Souza LAG.

numerous other applications. Thus, the main economic product of the Fabaceae of the Amazon is wood, notified by those used for noble purposes.

In the group of species that has been most used for its timber value, those whose uses and mechanical properties have already been investigated are classified, revealing their economic and industrial potential. In the research already carried out, it was

Scientific name	Characteristics and use of wood
Cedrelinga cateniiformis	Wood easy to saw, plan, nail and screw. It gets good finish. Used in light construction, furniture, general works of carpentry, joinery and finishing, floors, partitions, boxes, plywood and for the construction of vessels (internal).
Dalbergia spruceana	Very heavy wood, with violaceous core, which receives attractive treatment. Used in decoration coatings, joinery, segeria, ebanisteria, marquetry, turned and adornment objects, knife cables, brushes, boxes or notched cases. Good for offices.
Dicorynia paraensis	Hard wood and imputable, rich in silica. It is used in civil construction, shipbuilding, carpentry, segeria, cuttings and hydraulic works, dormant. It's flexible, elastic.
Dinizia excelsa	Wood very heavy and hard to cut, high resistance to the attack of xylophages and very resistant. Suitable for external uses such as poles, bridges, piles, sleepers, mains, for construction such as rafters, beams, slats, such as clubs and boards, stops, bodywork, wagons and shipbuilding.
Diplotropis martiusii	Very hard and resistant wood in contact with water, used in shipbuilding, in parts of boats such as hull, also in furniture, carpentry, for frames, doors, turned parts, crosses, poles, floorboards, clubs and civil construction in general.
Dipteryx odorata	Wood very heavy, hard to cut, very resistant to the attack of termites and rotting fungi. Indicated for civil construction, such as beams, rafters, slats, floor boards and clubs, door stops, liners, for external use as poles, mains, piles, crosslets, bodywork, shipbuilding and furniture.
Enterolobium schomburgkii	Heavy wood that receives good finish with high chandelier, so even employed in joinery, franchisees, construction in general, board for floors, door stops, tacos, good quality furniture and sleepers.
Hymenaea courbaril	The wood is hard and sturdy, employed in grinders, firewood, mains, portals, etc. Heavy construction, hydraulic works, bodywork, mills, poles, beams, barrel, etc.
Macrolobium acaciifolium	Reddish wood, compact, imputable. Used in carpentry, boxes, pulp and paper, good quality boards and joinery. It is very flexible, used in red furniture taking various shapes.
Peltogyne catingae	Hard and compact wood, with intense purple heartwood or purplish violet, resistant to decomposition, glossy polishing. Used in segeria, dormant, construction and shipbuilding, sculptures, fine joinery, ebanisteria, floor clubs and carpentry.
Vatairea guianense	The wood is heavy, with light brown heartwood, resistant to fungi and termites, easy to work and receives good finish. It is used in carpentry, crate, construction, industrial boxes, poles, etc.
Zygia racemosa	Very heavy wood, light yellow heartwood, resistant to fungi. Used in ebanisteria, luxury joinery, parquets, floor clubs, and construction in general, plywood, decorative laminates cutlery, walking sticks, dormant sands and adornment objects.

Source: [15–18].

Table 2.
General characteristics of wood of economic value and its jobs, for some species of Fabaceae of the Amazon.

also found that there is availability of wood-producing species for secondary use, such as firewood and coal, and that they can be used for less noble uses, such as azimbre, plywood, crate, etc. However, the high diversity in species demands the advancement of wood research of those little used by the lack of knowledge of its technological properties.

Table 2 contains information on some general characteristics of Amazonian tree wood, with information on its current use, among them some of the most valuable. Among them are *Cedrelinga cateniiformis*, *Dalbergia spruceana*, *Dinizia excelsa*, etc., expanding its potential for identification and commercialization in the timber, national and foreign markets. Most of the wood that reaches foreign markets is hard, heavy and resistant, indicating that the density of wood is an important indicator to define its potential for use.

4. Random characteristics of Fabaceae of timber importance in the Amazon

In opposite in the advance of knowledge of the technological properties of wood that defines its potential form of use, forestry research aims to support the recovery of the landscape and the potential of supplying raw material for the future. Historically, the exploitation of native trees is the source of raw material for numerous products and by-products, such as wood, medicines, cellulose and paper, food for fauna and man, fibers, oils and resins, gums, etc. There is a need for research on the silvicultural and economic potential of the species, adding value to biodiversity, especially in planting and reforestation actions, contributing to the conservation of forest resources. Some specific information for 45 random tree species of the Amazon region, with the popular name in Brazil, phylogeny, size characteristic, wood density and N_2 fixation ability are presented in **Table 3**.

Species	Popular name	Phylogeny (Tribe)*1	Tree height	Wood density (g cm^{-3})*2	N_2 Fixation
Caesalpinioideae					
Caesalpinia ferrea	Jucá	Caesalpinieae	Small	1, 19	No
Campsiandra laurifolia	Acapurana	Caesalpinieae	Medium	0,90–1,10	Yes
Cassia fastuosa	Chuva-de-ouro	Cassieae	Medium	0,60–0,70	No
Cassia grandis	Mari-mari sarro	Cassieae	Big	0,65–0,77	No
Cassia leiandra	Ingá-mari-mari	Cassieae	Small	0,86	No
Copaifera multijuga	Copaíba	Detarieae	Big	0,75–0,85	No
Crudia oblonga	Iperana	Detarieae	Big	0,70	No
Cynometra bauhiniifolia	Jutairana-preta	Detarieae	Medium	0,81	No
Dialium guianense	Jutaí-café	Cassieae	Medium	1,20	No

Species	Popular name	Phylogeny (Tribe)*1	Tree height	Wood density (g cm^{-3})*2	N_2 Fixation
Dicorynia paraensis	Angélica-do-Pará	Cassieae	Big	0,90	No
Dimorphandra parviflora	Faveira-de-anta	Caesalpinieae	Big	1,00	Yes
Hymenaea courbaril	Jatobá	Detarieae	Big	0,88–1,00	No
Macrolobium acaciifolium	Arapari	Detarieae	Big	0,65–0,75	No
Macrolobium angustifolium	Apeu	Detarieae	Medium	0,65–0,75	No
Mora paraensis	Pracuúba	Caesalpinieae	Big	0,83–0,96	No
Peltogyne paniculata	Mulateiro	Detarieae	Big	1,20	No
Sclerolobium hypoleucum	Tachi-preto	Caesalpinieae	Medium	0,55–0,75	Yes
Tachigali paniculata alba	Tachi-branco	Caesalpinieae	Big	0,55–0,75	Yes
Faboideae					
Acosmium nitens	Taboarana	Sophoreae	Medium	1,00	Yes
Andira inermis	Manga-brava	Dalbergieae	Big	0,70	Yes
Clitoria fairchildiana	Palheteira	Phaseoleae	Medium	0,51–0,54	Yes
Dalbergia spruceana	Jacarandá	Dalbergieae	Small	1,00–1,10	Yes
Dipteryx odorata	Cumaru	Dipterygeae	Big	1,15–1,19	No
Erythrina fusca	Mulungu	Phaseoleae	Medium	0,31–0,33	Yes
Hymenolobium pulcherrimum	Angelim-da-mata	Dalbergieae	Big	0,79	Yes
Ormosia excelsa	Tento-amarelo	Sophoreae	Medium	0,70–0,72	Yes
Platymiscium trinitatis	Macacaúba	Dalbergieae	Big	0,95	Yes
Swartzia laevicarpa	Saboarana	Swartzieae	Medium	0,80	Yes
Swartzia polyphylla	Arabá	Swartzieae	Big	0,64	Yes
Taralea oppositifolia	Cumaru-da-beira	Dipterygeae	Big	0,82–0,95	No
Vatairea guianense	Fava-mutum	Dalbergieae	Big	0,65–0,80	No
Mimosoideae					
Albizia saman	Bordão-de-velho	Ingeae	Big	0,45–0,60	Yes
Anadenanthera peregrina	Angico-vermelho	Mimoseae	Medium	0,93–0,95	Yes

Species	Popular name	Phylogeny (Tribe)*1	Tree height	Wood density (g cm^{-3})*2	N_2 Fixation
Dinizia excelsa	Angelim-pedra	Mimoseae	Big	0,98–1,15	No
Enterolobium maximum	Fava-tamboril	Ingeae	Big	0,60	Yes
Enterolobium schombugkii	Orelha-de-negro	Ingeae	Big	0,75–0,85	Yes
Hydrochorea corymbosa	Faveira-do-igapó	Ingeae	Medium	0,55	Yes
Inga alba	Ingá-turi	Ingeae	Medium	0,50–0,70	Yes
Inga edulis	Ingá-cipó	Ingeae	Small	0,76	Yes
Inga splendens	Ingá-açu	Ingeae	Small	0,55	Yes
Parkia multijuga	Pinho-cuiabano	Parkieae	Big	0,50	No
Parkia nitida	Faveira-benguê	Parkieae	Medium	0,40–0,55	No
Parkia pendula	Visgueiro	Parkieae	Big	0,80–0,85	No
Pentaclethra macroloba	Paracaxi	Parkieae	Medium	0,61–0,88	Yes
Stryphnodendron guianense	Faveira-camuzé	Mimoseae	Medium	0,48	Yes

*1[19] www.ildis.org; *2 Values compiled from the technical literature.

Table 3.
Scientific and popular name, subfamily, tribe, size, wood density and symbiotic n2 nodulation ability of 45 species of Fabaceae native to the Amazon.

The Fabaceae of wood interest are classified in all subfamilies and many have large size, but also medium or small, varying with the taxon. There are large trees that occupy the upper canopy of the tropical forest in areas of no hydromorphic soil as *Dinizia excelsa* that can reach 55 m high or in flooded forests such as *Mora paraensis*, which grows up to 50 m, but also species such as *Dalbergia spruceana* which, despite the small size, has economic value in the timber market. Some of the largest trees in the Amazon are very old and have an estimated age of up to 1200 years, as verified for *D. odorata*, by dating ^{14}C, in a tree that had trunk diameter of ±120 cm, with an estimated growth rate of ±0.1 cm year^{-1}, while *Parkia pendula*, with trunk diameter of 110 m corresponded to the age of ±200 years with an estimated growth rate of ±0.65 cm year^{-1} [20].

The timber trade is hampered by the little knowledge of the wood itself and low identification at the species level by the high variation of popular names, yet in the listings of timber exported from the Amazon, angelim, jacarandá, jatobá, sucupira, macacaúba, etc., are frequent presences. The density values of the wood are directly related to its potential for use, so the light woods have density < 0.50 g cm^{-3}, medium density woods have between 0.50 and 0.70 g cm^{-3} and the stiffest and heavier woods >0.70 g cm^{-3}. The woods of higher density are harder and heavier viable for uses already described, but also for energy production (firewood, alcohol and coal) and the woods with low density are much lighter and able for the production of pulp and paper, light woods and rich in thin-walled fibers.

For the sustained exploitation of timber resources, it is necessary to consider that in tropical forests, some ecological and economic characteristics can determine the increase or decline of forest species populations. The commercial value, limited geographical distribution, little dispersal ability, slow growth and reduced number of juveniles, will affect the decline of populations if the species is exploited by severe logging [21]. Obtaining more forestry and autecology information of species with greater potential management and cultivation is an important step for the preservation of these natural resources and the main challenge is the great biodiversity and numerical grandeur of wood-producing species.

Additionally, there is a property that also characterizes Fabaceae: the ability to associate with soil bacteria, from the rhizobium group, producing small root nodules, an effective site for biochemical and enzymatic processes that allow the dynamics of biological fixation of N_2 - BNF. Numerous tree legumes, but not all, can develop root nodules and fix N_2, adding to these species another role besides the productive, that of providing services to increase the entry of NH^{4+} into ecosystems in imbalance [22]. In soils altered in its organic matter stocks, BNF has a strategic agroecological function. N_2 fixer trees in symbiosis with Rhizobia are designated nitrogen-fixing trees – NFTs.

Among the timber species, several with nodulation species of economic importance stand out among the species, they are *Anadenanthera peregrina*, *Campsiandra laurifolia*, *Hymenolobium pulcherrimum*, *Platymiscium trinitatis*, etc. On the other hand in several Fabaceae of wood importance the nodulifiable ability has not been proven, e.g. *Dialium guianense*, *Dinizia excelsa*, *D. odorata*, *Peltogyne paniculata*, etc. It is noted that the fixing ability of N_2 in Fabaceae evolved mainly in species of the subfamilies Mimosoideae and Faboideae, and has less representation among Caesalpinioideae, where only species cited for the Caesalpinieae tribes had this natural ability (**Table 3**).

The N_2-fixing Fabaceae have advantages over other plants, due to the natural absorption ability of atmospheric N in the form of NH^{4+}, and BNF is an economically and biologically rewarding process, contributing to the productivity of the soil-plant-animal system. The current concepts of Agroecology have emphasized the use of NFTs in forestry or agricultural production systems with particular importance in the composition of species in Agroforestry Systems that seek sustainability in nitrogen. Thus, the Fabaceae of the Amazon emerge as an important element for sustainable production systems in the future.

5. Silvicultural bases for the cultivation and management of woody Fabaceae for the future

As for their use and practical use, tree legumes can be classified into three distinct groups: (1) trees that produce wood and miscellany of by-products such as firewood, oil, resin, tannin, coal and cellulose; (2) forage and human food trees; and (3) trees that aid soil fertility in agricultural practices such as the establishment of retention ranges, shelter areas, erosion control and increase of N status in the soil in agricultural rotation models or in rotation systems whose benefit is the service performed by trees to the environment.

Regardless of the choice of species, basic forestry knowledge is indispensable. Among the Fabaceae there is a wide variety of fruit forms, being possible to define

14 different morphological types [23]. An illustration of the morphological aspect of the fruits and seeds of Fabaceae from the Brazilian Amazon is shown in **Figure 4**. For the advance in basic forestry research of Fabaceae of the Amazon, there is a need to ensure the correct identification of taxa in existing herbaria. The following is the application of drying techniques, cleaning and fruit processing, germination studies, seedling production and sequential forest plantations contributes to the generation of

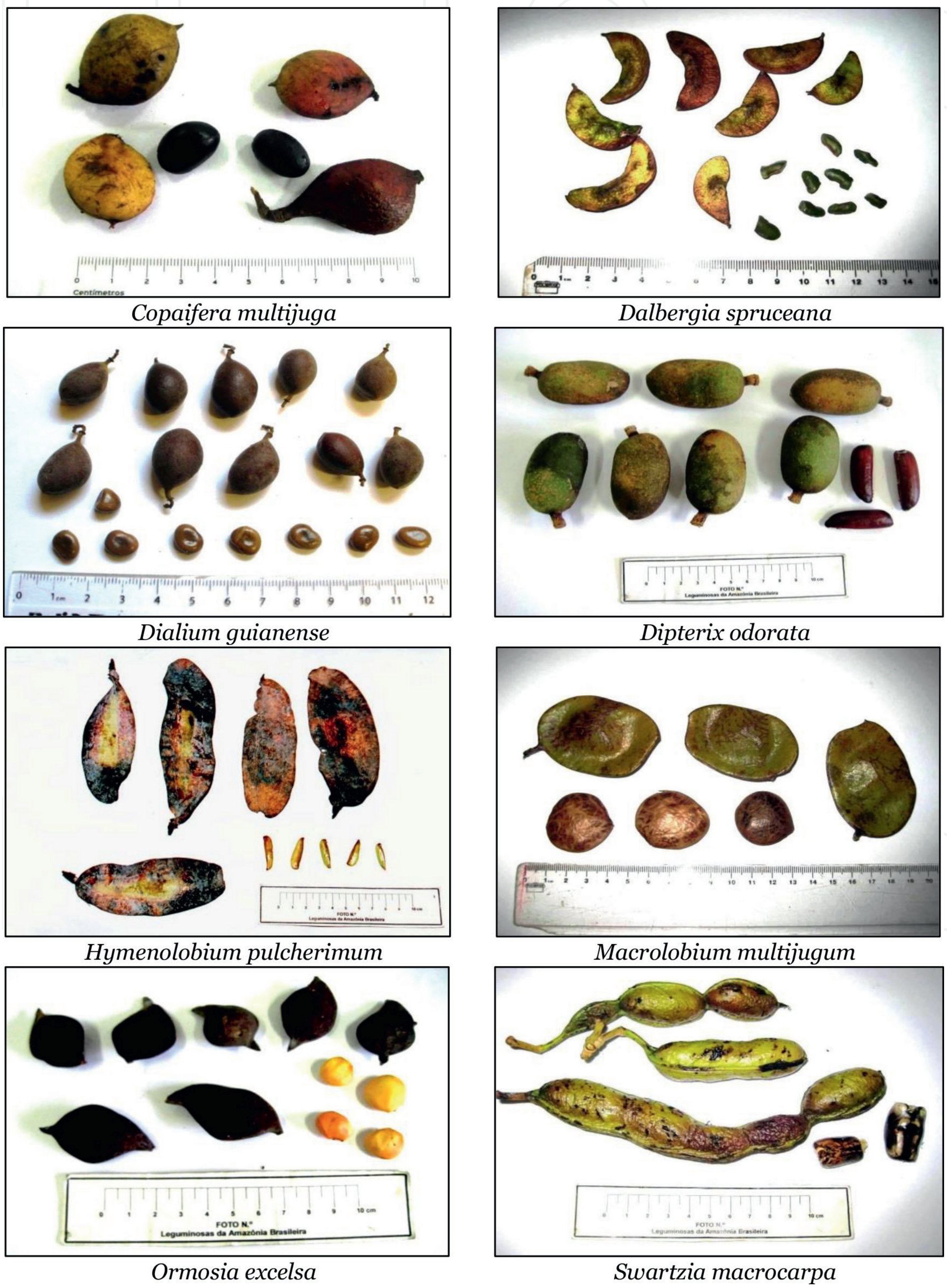

Figure 4.
Morphology of fruits and seeds of Fabaceae species from the Amazon region of wood interest. Photos: Souza LAG.

basic information to identify the species with the greatest potential, followed by their silvicultural use.

In the tropical forest, tree populations with higher potential for regeneration or management should present the following ecological parameters: (1) Seed dispersal facility; (2) Abundance of rods in regenerating forests; (3) Good growth rate; (4) Good regrowth capacity after cutting/burning; (5) Fire resistance; (6) Good breadth of geographical distribution; and, (7) Plenty of adults [21].

In Brazil, at the National Institute of Amazonian Research - Inpa, in Manaus, Amazonas, the research actions follow sequential steps to identify the species with higher potential for management and planting. In bioprospecting in natural or altered areas throughout the region, after fruit collection, the studies follow the following flow: → correct botanical identification of the taxon and its ecological group; → evaluation of fruit and seed production; → seed resistance to desiccation germination of seeds quickly and homogeneity → evaluation of seedling production in nurseries → identification of N_2 fixing ability → phytosanitary aspects and survival after planting → planting definitive to identify rapid growth, rusticity, high biomass production and adaptation to dystrophic soils→ progeny assays, genetic improvement and more advanced stages of research.

Basic forestry studies prioritize the generation of information that can help the planting of species contributing to their conservation and value of biodiversity resources. To contribute to the planting on a larger scale of little-known native species, the basic determinations in the fruit processing phase provide information for seed acquisition or marketing of propagules. Among the relevant information scans are the average weight of the fruits and in the processing phase the fruit purity test provides data on the investment of the fruit in seed formation, and can be an important indicator to evaluate the quality of a batch of intraspecific fruits.

The number of seeds per kilo and the weight of 1000 seeds are auxiliary information for seed acquisition, and, considering their size, provide indicators for the later forestry stages such as seedling production, defining the size of the container and total amount of substrate to be used for each species, managed in the nursery phase. Some of these basic determinations for 45 species of Fabaceae of wood importance are presented in **Table 4**. There is great variety in the fruit size of Fabaceae trees, some developing very large and heavy fruits such as *Inga edulis* whose fruits reach almost 400 g or *Swartzia polyphylla* with just over 200 g. The heavy fruits are commonly dispersed by weight, and are deposited under the canopy of the mother tree, and can then be distributed by water or wildlife.

In the flooded forests of Igapó, vegetation that occurs in black water rivers in areas with nutrient scarcity, large and heavy fruits may have structures that allow floating, and some species with large and voluminous fruits such as *Cassia grandis*, *Mora paraensis* and *Vatairea guianense* form their own comparatively mass group. In the Igapó, the fruits containing seeds with high biomass compensate for the loss of nutrients in the initial phase of seedling establishment and in the floodplains, in sedimentary basins with high nutrient availability, the seeds may be small, but produce elongated seedlings, suitable for survival in regular flood cycles [24].

There are also species with small fruits with weight < 1 g as observed for *Acosmium nitens*, *D. guianense*, *Ormosia excelsa* and others and also a large group of intermediate weight defined in the range of the median fruits. The size of the fruit, therefore, can sometimes be associated with vigor and growth capacity of seedlings and, therefore, development in juvenile stages. For this, each self-ecological species the investment in the fruit in the formation of seeds, also defined as fruit purity index, which is very varied and is not related to its size (**Table 4**).

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Specie	Fruit weight	Weight of 1000 seed	Purity (%)	Nº of seeds kg^{-1}
	g			
Caesalpinioideae				
Caesalpinia ferrea	7,51	197,7	17,87	5.051
Campsiandra laurifolia	80,92	9.629,3	59,57	104
Cassia fastuosa	39,29	49,3	15,72	20.408
Cassia grandis	194,41	629,7	17,49	1.608
Cassia leiandra	385,60	540,86	11,84	1.885
Copaifera multijuga	7,77	2.562,6	21,90	372
Crudia oblonga	28,07	10.330,2	64,88	118
Cynometra bauhiniifolia	1,44	1.225,5	87,78	816
Dialium guianense	0,47	144,3	37,54	6.977
Dicorynia paraensis	0,87	257,6	45,50	3.944
Dimorphandra parviflora	11,09	241,64	22,25	4.141
Hymenaea courbaril	25,52	3.816,9	32,79	262
Macrolobium acaciifolium	8,91	5.506,4	63,90	190
Macrolobium angustifolium	10,85	4.558,4	52,38	222
Mora paraensis	126,92	91.033,0	67,04	12
Peltogyne paniculata	0,74	445,8	58,72	2.243
Sclerolobium hypoleucum	0,99	178,0	15,96	5.620
Tachigali paniculata alba	0,52	173,6	24,40	5.720
Faboideae				
Acosmium nitens	0,43	203,8	43,88	4.927
Andira inermis	24,61	9.573,5	38,93	104
Clitoria fairchildiana	18,84	604,8	22,89	1.657
Dalbergia spruceana	2,03	1.285,3	74,69	782
Dipteryx odorata	19,40	2.222,4	9,87	450
Erythrina fusca	4,30	368,6	41,02	2.724
Hymenolobium pulcherrimum	0,76	341,3	4,09	4.298
Ormosia excelsa	2,65	1.468,8	55,42	680
Platymiscium trinitatis	0,61	493,9	58,20	2.029
Swartzia laevicarpa	54,99	17.399,2	47,00	58
Swartzia polyphylla	203,53	66.967,7	44,56	15
Taralea oppositifolia	10,77	4.069,3	38,10	247
Vatairea guianense	93,17	44.448,1	47,30	23
Mimosoideae				
Albizia saman	13,22	203,9	26,50	4.930
Anadenanthera peregrina	2,30	158,2	29,80	6.345

Specie	Fruit weight	Weight of 1000 seed	Purity (%)	N° of seeds kg^{-1}
	g			
Dinizia excelsa	10,31	66,8	31,96	17.681
Enterolobium maximum	75,97	1.020,0	18,60	953
Enterolobium schombugkii	16,53	54,7	5,75	18.289
Hydrochorea corymbosa	1,64	64,88	18,28	15.470
Inga alba	4,50	203,72	46,04	4.909
Inga edulis	395,05	3.594,0	17,18	279
Inga splendens	104,90	1.710,0	20,91	588
Parkia multijuga	177,42	6.625,8	44,70	155
Parkia nitida	97,81	1.746,3	33,70	573
Parkia pendula	11,58	170,50	60,00	9.870
Pentaclethra macroloba	172,37	6.333,4	26,31	158
Stryphnodendron guianense	3,91	74,2	22,81	13.491

1 – Determinations made at Inpa, in Manaus, AM, Brazil.

Table 4.
Fruit weight, percentage of purity, number of seeds per kilo and weight of 1000 seeds of Amazonian legumes of wood interest.[*1]

Among the species the greatest investment in seed formation in relation to the fruit was verified in *Cynometra bauhiniifolia*, where the purity indexes (%) of the fruits reach 87.78%, but also *Campsiandra laurifolia* and *Macrolobium acaciifolium* all of the flooded forests, which possibly relate to their dispersal syndrome, which in this environment is by hydrocoral process. There is a group of species with low purity in fruits, with little investment in seed formation, which in *Hymenolobium pulcherrimum* is <5%, and there are others with <20% such as *Cassia fastuosa*, *D. odorata*, *Enterolobium maximum*, etc. Many species have intermediate values, reflecting their variety and diversity.

Basic forestry determinations of the number of seeds per kilo and/or the weight of 1000 seeds are important for the acquisition and/or marketing of germplasm for planting or reforestation. A kilo of *Cassia fastuosa* seeds can contain >20,000 seeds, because they are small and light seeds. For other species, in 1 kg of seeds there are >10,000 seeds such as for *Cassia leiandra*, *Dinizia excelsa*, *Enterolobium schomburgkii*, *Stryphnodendron guianense*, etc.

On the other hand, in 1 kg of *Mora paraensis* seeds is the weight of only 12 seeds and the high individual weight is a hindrance to its acquisition, regardless of its timber value. Thus also, in 1 kg of *Swartzia polyphylla* seeds there are only 15 seeds, 23 in *Vatairea guianense*, and 58 of *Swartzia laevicarpa*. They are large fruits and seeds, characteristic of the flooded areas of Igapó.

The acquisition of 1000 seeds for planting trees of various species of trees in the Amazon exceeds 10 kg. In this group, for the species that has heavier seeds, *Mora paraensis*, to gather 1000 seeds is necessary more than 90 kg of seeds. In contrast, to dispose of 1000 seeds of *Cassia fastuosa* are <50 g of seeds.

There is a sequence of research steps generating applied silvicultural technology, which will not be explored at this time. In seed germination there are large differences between species regarding the classification for desiccation tolerance and also a predominant characteristic among Fabaceae: the existence of dormancy mechanisms in seeds, associated with the impermeability of the integument, which can be overcome by the application of scarification methods.

They follow the experimental research on seedling formation in forest nurseries followed by definitive planting for selection of the best-developing species. The oldest experimental plantations with native species are more than 60 years old and over time new groups of species have been evaluated to identify their potential for cultivation and favor reforestation actions and forest production. In more advanced phases of forest research, progeny tests are performed for selection of superior germplasm in forest breeding programs.

6. Conclusions

Seen from above, the Amazon rainforest often appears some floristic and relief uniformity. Conversely, the large extent of continuous natural forests is a mosaic of different ecosystems and overlapping ecotone zones, constituting different environments, and biodiversity in fauna and flora, on irregular topography. The botanical inventories conducted in the Central Amazon have pointed out, in general, a high diversity of Fabaceae in its floristic composition [13], which leads us to propose strategies that can provide instruments for the planned use of these resources. The assessment of the economic potential of biodiversity becomes a priority in areas of high diversity.

In practical terms, the results of these studies could potentially reach the following groups of beneficiaries: the industrial chemical sector of wood products; reforestation companies for timber production or for species suitable for agroforestry systems and for the recovery of degraded areas; small farmers' communities, generating production alternatives; the scientific community, through the dissemination of specialized information; and, the general population, through the dissemination of technical information made accessible to a larger audience.

Recognizing that wood is the most valuable product of Amazonian Fabaceae, there is no doubt that the role of many species in reforestation and recovery of eroded soils may be greater than the current one. Reforestation with legumes inoculated with bacteria from the rhizobium group can be a promising alternative in Amazonian agroecosystems contributing to nitrogen sustainability. The planting of NFTs has been successful in areas disturbed by poor land use, such as those resulting from abandoned pastures and mining activities [25].

In the Brazilian Amazon, even with the maintenance of protection and conservation areas distributed in this biome, such as National Parks, Biological Reserves and Ecological Stations, Natural Protection Areas, etc., the economic potential of wood has been exploited for economic purposes. Despite their economic value for the timber potential, Fabaceae are important in the recovery of degraded areas and in the reforestation of marginal soils to reduce the costs of wood produced as well as obtaining raw material for industrialization [26]. For the products and services that fabaceae species offer is certainly an important resource for exploration, preservation and conservation of biodiversity in the Amazon and, in this third millennium, its valorization to the world.

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