Kuswata Kartawinata, Roemantyo,
Ary Prihardhyanto Keim,
& Wawan Sujarwo

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Publisher's Note

The BRIN Publishing has the duty and responsibility to help scientists in all fields of sciences to disseminate their research results in the form of books in an effort to make them available to public at large. As such BRIN Publishing helps to make the Indonesian population comprehend scientific research outcomes and able to implement them in practice for the welfare of the people as well as making research findings available to scientific communities throughout the world. In this context, BRIN Publishing helps with the publication of the book entitled 'Natural Vegetation and Ethnobotany of Bali', after having gone through the process of reviewing done by appropriate specialists and editing by the Board of Editors of BRIN Publishing.

This book aims at compiling and documenting current status of natural vegetation and ethnobotany of Bali. It is an attempt to complement and enrich not only the natural vegetation but also the ethnobotany that includes the cultural, religious, and daily uses of plants by the Balinese. The book presentation covers vegetation classification and description on structure and composition of vegetation types, and a treatise on the ethnobotany. The target readers of the book is public at large, including students, lecturers, scientists, eco-tourism developers, conservationists, and others.

The publisher hopes that the book can be used as a reference for policy makers on holistic understanding of natural vegetation and ethnobotany, as well as their interac-

tions with the environment. Therefore it will enable land use planners, for instance, to determine the best utilization of plant resources in the context of sustainable development.

BRIN Publishing

Foreword

The entire islands of Indonesia are covered by a vast extent of a diversity of vegetation forming the major component of terrestrial ecosystems, which in turn constitute the biodiversity of the country. Different types of natural ecosystems of Indonesia have been described briefly by Kartawinata (2013), in which he accepted the proposition that ecosystem types are equivalent to and can be expressed as vegetation types (Mueller-Dombois & Ellenberg, 1974; Specht, 1981). Although the diversity of natural ecosystems presented by Kartawinata (2013) has been used by Ministry of Environment (2013) in the production of the book on '*Deskripsi Peta Ekoregion Pulau/Kepulauan*' (Description of Map of Islands/ Archipelago Ecoregion) in Indonesia, it requires further effort to develop and complement it in more detailed so as to satisfy the greater need of the use of vegetation data for various scientific and practical purposes.

The present book on 'Natural Vegetation and Ethnobotany of Bali' is a good complement not only for the enrichment of the vegetation aspects but also for the amelioration of the ethnobotanical perspectives, that include the cultural, religious, and daily uses of plants by the Balinese. The targeted readers of the book are public at large, including students, lecturers, scientists, eco-tourism developer, conservationists and others.

Vegetation data are very important for many purposes, including utilization and conservation of biodiversity,

vegetation restoration, and for further scientific investigation in ecology and other disciplines. The uses of existing forest vegetation data, for example, has been shown by Kartawinata together with hundreds of scientists from many countries in the world in the production of research papers on climatic controls of decomposition and forest-tree symbioses (Steidinger et al., 2019), phylogenetic classification of the world's tropical forests (Slik et al., 2018), the global abundance of tree palms (Muscarella et al., 2020), and many others.

Indonesian Institute of Sciences (LIPI), which is now integrated into BRIN, has been involved in research on vegetation since 1975 and the results have been published in various journals, but only at low intensity. As yet, they represent only a fraction of the knowledge of the vast extent of the natural vegetation of Indonesia, which has been depleting at a very rapid rate due to various conversion to a variety of utilization and to uncontrolled destruction. There is, therefore, a great need to intensify the studies of natural and successional vegetation in both protected and non-protected areas, including such aspects of floristic composition and structure of plant communities along with altitudinal gradients, complemented with soil and climatic data to understand the relationships between vegetation and environmental factors.

The way people interact with plants and their natural vegetation is always fascinating, so that we should also give attention to undertake research on ethnobotany in various vegetation types, i.e. vegetation in fresh water, tidal and peat swamps, limestone habitats and ultrabasic soils, as well as seasonal forests, montane forests, savannas, and grasslands, as to date information and data about these plant communities are still scanty. The results of such stud-

ies are not only synthesized to understand geographical distributional patterns and cause of patterns of species richness, but also for utilization, management and conservation of biodiversity.

Bogor, June 2022

Dr. Anang Setiawan Achmadi
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Preface

Vegetation protects and ensures the sustainability and survival of human being on earth as vegetation constitutes the main component of any terrestrial ecosystem. In an ecosystem, human beings, other organisms, vegetation, and environment are interacting. Climate change, increasing poverty, and deteriorating health and welfare of people are attributed a great deal to the destruction of vegetation covering the earth's surface by human destructive activities.

Vegetation is a mosaic of plant communities in a landscape (Küchler, 1967). Plant community is a group of a variety of plant species growing in an area that are occurring in a repeated fashion. A vegetation reflects the product of an interaction between plants, animals, and their environment (Webb & Tracey, 1994). In a community and a vegetation, we deal only with the plant component. If we integrate environmental factors (physical and biotic factors) into a community or vegetation, we will end up forming an ecosystem. Vegetation consisting of a plant community forms the dominant component of an ecosystem and is most easily identified. Vegetation can be used to define the boundary of an ecosystem (Mueller-Dombois & Ellenberg, 1974, 2016). It is frequently used to identify, substitute, and represent an ecosystem, as the live of the majority of animals is dependent on vegetation (Specht, 1981). A vegetation type is, therefore, equal to an ecosystem type. The concept has been used in

the book on diversity of natural ecosystems of Indonesia by Kartawinata (2013).

Bali is globally famous for its people, culture, and natural beauty that constitute the basis for tourism development. They are directly and indirectly determined by its environment, particularly the vegetation component. In Bali, we can find a diversity of natural vegetation types extending from swampland and dry land on the coastal areas, to the tops of the mountains with climate ranging from wet to seasonally dry. Most of the lowland natural vegetation has been converted into various land uses including gardens, rice fields, plantations, touristic areas, and human settlements. Currently, the remaining natural vegetation can be found mostly in areas with high elevation. Information and data on different types of natural vegetation are meager and scattered in various literatures, which are not always easily accessible to anyone who needs them because they have not been recorded and synthesized systematically.

Impressed by magnificent touristic wonder, visitors tend to ignore the ecological component of the touristic values, hence why people including naturalists failed to record the kind of plants forming the beauty of Bali. This is aggravated by the assumption that flora of Bali is similar to the Java's. It is recently discovered (Girmansyah et al., 2013) that Bali has not been floristically well explored as testified by a meager number of herbarium specimens represented in the collection at the National Herbarium (Herbarium Bogoriense) and other herbaria in the country. To date no one has ventured to write the flora of Bali until a group of botanists took an initiative to start writing the Flora of Bali and has published an Annotated Checklist of the Flora of Bali (Girmansyah et al., 2013). The present book on natural vegetation and ethnobotany of Bali will enrich and complement the future flora of Bali.

In contrast to the flora in general the ethnobotanical studies of Bali, especially on the daily uses of plants for food, cultural needs and religious rituals, relatively abound but are scatteredly published in various journals and reports. We compiled and synthesized available published and unpublished data including field notes on vegetation in Bali. The book presentation covers vegetation classification and description on structure and composition of vegetation types, and a treatise on the ethnobotany. It is preceded with the introduction formulating the concept of vegetation and short accounts on climate, geography, geology, soils, and phytogeography. The description of vegetation is not final and should be improved through further studies. In this book we are dealing only with natural vegetation. From the point of view of conservation and animal ecology, a knowledge of nature of the original vegetation cover is of the utmost importance. It is not possible to understand distribution of species of both plants and animals without acquiring knowledge on natural vegetation.

Natural vegetation (Mueller-Dombois & Ellenberg, 1974, 2016; Mueller-Dombois & Fosberg, 1998) or known also as wild vegetation (Eyre, 1971) is a mosaic of plant communities within a landscape undisturbed by human activities. It adapts itself to its environment, hence it is in a state of harmonious relationship. Natural vegetation is not only a component of biological diversity that provides natural resources but also has important roles in many natural processes, such as hydrology and improvement of climate.

Data on vegetation and ethnobotany are very important, it forms a basis for utilization and conservation of plant diversity and other natural resources. They are collected and compiled not only for scientific purposes, but also for a variety of practical purposes, such as ecosystem utilization, management, and conservation. Ecotourism is dependent

greatly on the information of natural vegetation. Holistic understanding of ethnobotany and natural vegetation as well as the interaction with the environment will enable land use planners, for instance, to determine the best utilization of natural resources in the context of sustainable development.

The objectives of writing this book are to (1) make available basic information to students, scientists, and public at large; (2) identify and comprehend vegetation and ethnobotany; (3) encourage further research on the ecology of vegetation and ethnobotany; (4) provide information to support biodiversity, conservation, and environmental education as well as ecotourism; (5) share basic data and information to decision and policy makers so that they can manage, utilize, and conserve biodiversity for sustainable economic development and people welfare. Despite many shortcomings, we believe that the description of natural vegetation and the ethnobotany of Bali are scientifically acceptable. Moreover, readers can provide criticisms and additional information to enrich the values of the book.

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Introduction

In this chapter, we described terrestrial and aquatic existing in Bali as well as its potential natural vegetation. Primary and secondary successional communities are briefly discussed in the descriptions of various natural vegetation types. We exclude man-made vegetation, such as agricultural lands, rice fields, gardens, home-gardens in human settlement, fruit orchards, timber plantation, fish ponds, etc. In the account on ethnobotany we included vegetation in all ecosystems, especially on the daily uses of plants, i.e., medicine, food, cultural needs, religious rituals, building materials, etc.

A. Natural Vegetation

Vegetation is the total plant cover in an area consisting of a mosaic of plant communities in a landscape (Küchler, 1967). Plant community is a group of population of a variety of plant species growing in an area and the groups are occurring in a repeated fashion. The group can be well described by recording the identity and growth form of the most abundant species, species who have large dimension or the most unique species in the community (Eyre, 1971; Mueller-Dombois & Fosberg 1998; Mueller-Dombois & Ellenberg, 1974, 2016). Thus a community does not consist of only a list of component species but also of species characterized by its largest contribution to the uniqueness of the structure and composition.

Vegetation should not be confused with flora. In a flora usually the locality of plants are indicated, but all plants are treated equally according to their taxonomic identity. In a vegetation, the plants are not treated equally, but distinguished according to their roles in the locality where they grow and in the community they form (Mueller-Dombois & Fosberg, 1998).

A vegetation reflects the physiognomy (external appearance) of an interaction between plants, animals, and their environment (Webb & Tracey, 1994). In a community and a vegetation, only the plant component is described. Integrating environmental factors (physical and biotic) into a community or vegetation will result in the formation of an ecosystem. Vegetation is a plant community which forms the dominant component of an ecosystem and is the most easily identified. Vegetation can be used to define the boundary of an ecosystem (Mueller-Dombois & Ellenberg, 1974, 2016). It is frequently used to identify, substitute, and represent an ecosystem, as the live of the majority of animals is dependent on vegetation (Specht, 1981). A vegetation type is, therefore, equal to an ecosystem type.

Vegetation units and patterns may be similar within a very extensive area. Physiognomy, a structural and functional characteristic of vegetation, is frequently dependent on regional climate, geomorphology, soil as a substrate, and disturbance (Mueller-Dombois & Fosberg, 1998). Based on such factors, on a landscape scale we may be able to distinguish various vegetation types, such as mangrove forest, lowland rain forest, montane rain forest, and subalpine forest, which may be known also as physiognomic environmental vegetation types (Mueller-Dombois & Fosberg, 1998; Mueller-Dombois & Ellenberg, 1974, 2016). Only below these levels, floristic composition is considered important to determine whether a vegetation unit, known as an as-

sociation, has a restricted distribution, such that the species combination at the association level is also restricted (Mueller-Dombois & Fosberg, 1998).

The role of plants is first distinguished according to lifeform, such as trees, shrubs and, herbs, including grasses, most ferns, and bryophytes. Their roles are further distinguished by the more detailed functions, such as tolerance towards shading or direct sunlight, and tolerance towards actual characters, including abundance, distribution, and environmental constraints (Mueller-Dombois & Fosberg, 1998; Mueller-Dombois & Ellenberg, 1974, 2016). Plant species form the pillar composing plant communities, which together constitute vegetation of various region.

Plant's environment include biotic, chemical, and physical environment, which jointly designated as habitat (Walter, 1971). A habitat consists of an area covered by vegetation, the geographic location frequently known as site, climate, topography, soil, and other factors affecting land covered by vegetation, which also include disturbance, interaction among plants, and interaction between plants and other organisms living within the vegetation (Mueller-Dombois & Fosberg, 1998).

Natural vegetation (Mueller-Dombois & Ellenberg, 1974, 2016; Mueller-Dombois & Fosberg, 1998) or known also as wild vegetation (Eyre, 1971) is a mosaic of plant communities within a landscape undisturbed by human activities. It adapts itself to its environment, hence it is in a state of harmonious relationship. Natural vegetation is not only a component of biological diversity that provides natural resources but also have important roles in many natural processes, such as hydrology and improvement of climate. It is, therefore, coverage, quality, and diversity of vegetation within every landscape call for maximum conservation. Without sufficient scientific data and information, natural

vegetation should not be simply converted to any forms of land use to satisfy human needs.

Plant communities may function as an indicator of environmental condition. They are not only responsive to one environmental factor, but also to groups of interacting factors. Plant communities integrate all effects and are very sensitive to and interact with various changes in environmental equilibrium. Structure, species composition, and geographic distribution are determined by environmental factors, in particular climate and soils. The relationship between plant communities and soils is very close, hence it may be considered as one entity (Mueller-Dombois & Ellenberg, 1974, 2016; Mueller-Dombois & Fosberg, 1998).

Different vegetation types may be mapped out at different scales for various purposes. For instance Whitmore (1986) has mapped out in a small scale the vegetation of Indonesia and neighboring countries constituting the phytogeographic region of Malesia (Brunei Darussalam, Malaysia, Philippines, Singapore, Papua New Guinea and Timor Leste). Others have made local vegetation, including Laumonier (1997) who produced vegetation maps of Sumatra, and Steenis and Schippers-Lammerste (1965) have published general vegetation map of Java. The Ministry of Environment (2013) published the description of the map of Bali-Nusa Tenggara ecoregion. The map of generalized potential natural vegetation of Bali on a larger scale has been produced in the present book as shown in Figure 3.2. Much of the lowland natural vegetation has been converted into various land uses, including agricultural lands, settlements, and touristic areas. These man-made vegetation types are excluded from the treatment of vegetation in this book.

In this book, our discussions are centered on a landscape scale, related to geomorphological characteristics, includ-

ing the controlling climate-physiographic factor. Whenever possible or needed, floristic diversity is also discussed. We describes terrestrial and aquatic existing, potential natural vegetation of Bali and exclude such man-made vegetation such as agricultural lands, rice fields, gardens, home-gardens in human settlement, fruit orchards, timber plantation, fish ponds, etc.

Primary and secondary successional communities are briefly discussed in the descriptions of various natural vegetation types. Primary successional communities are naturally developing communities on new substrates including volcanic ash deposits and lavas produced by volcanic eruption, virgin soils previously not inhabited by plants including soils left exposed by landslides, mud deposits, and sand deposits such as sand dunes and sandy beaches. Secondary successional communities refer to plant communities naturally developing on exposed old substrates, whose original plant communities have been removed by various destructive human activities, including clear-cut natural forests by timber logging and establishment of dryland cultivation (*ladang*), and communities developed in abandoned lands.

Vegetation data are very important and form a basis for utilization and conservation of plant diversity and other natural resources. It is collected and compiled not only for scientific purposes, but also for a variety of practical means, including forest exploitation, plant community restoration, animal husbandry, etc. Holistic understanding of natural vegetation and its interaction with its environment will enable land use planners for instance to determine the best utilization of natural resources in the context of sustainable development.

B. Ethnobotany of Bali

Ethnobotany is generally defined as division of botany concerned with the interactions between people and plants (Balick & Cox 2021). In this context we know that since earlier times people have used plants. Ethnobotany is important in tropical countries where cultures are undergoing rapid change. Many scientists have stressed the urgent need of ethnobotanical documentation to contrast the rapid decline of traditional knowledge due to plant extinction and, above all, to the disappearance of traditional cultures. It is important to document plants traditionally consumed within a particular geographical and cultural context. Such documentation is also necessary to understand cultural issues related to any use-categories in ethnobotanical study. We believe the documentation will provide quality information on how and why people use plants and will contribute to the conservation of biological and cultural diversity.

Ethnobotanical evidence in Bali identifies strongly with Hindu religious customs and traditions. In the past, their economy was based on wild natural resources, while nowadays is based on agriculture and tourism. The arrival of ecotourism to some Bali traditional villages presents a unique array of prospects and challenges for the local population, and for their relationships with nature. With a significant proportion of visitors being foreign and wealthy, at least by local standards, this once isolated region has been bombarded by the cultural and material influences and excesses of the developed world.

The island of Bali continues to be rich in Traditional Ecological Knowledge (TEK) as confirmed by a general inventory on traditional plant usages (Astuti et al., 2000), by detailed investigations on medicinal, aromatic, and cosmetic plants (Leurs, 2010), and supported by studies on wild and semi-wild edible plants (Sujarwo et al., 2016). Bali's traditional

foods and nutraceutical culture includes a wide variety of plants that are cultivated and gathered in forests or grown in home gardens that have a long tradition (Sujarwo & Caneva 2015; Sujarwo et al., 2015; Sujarwo et al., 2016).

Balinese traditional communities long ago began implementing a local customary law concerning the sustainable use of renewable natural resources (Sujarwo et al., 2014). The main focus of the law with regard to nature concerns the extraction of plants, for example building materials. From a scientific viewpoint, sustainability of the plant uses should ideally be based on a knowledge of the availability of resources, the potential for species regeneration, and the rate of resource use (Obiri et al., 2002; Lawes & Obiri, 2003; Gaugris & van Rooyen, 2009). Since most resources in this case are used by local people—almost always traditional—societies, a biological assessment should be accompanied by a social evaluation using an ethnobotanical approach (Posthouwer et al., 2016). Although traditional Balinese communities have access to natural areas and plant resources are freely available to them, the sustainable use of natural, renewable resources is evaluated at a tribal community level through a system known as *awig-awig* (Balinese local customary law) (Sujarwo et al., 2014).

The use of indigenous plant species is reflected in the high level of botanical knowledge possessed by the Balinese. However, culture is as dynamic as the environment, and changes are inevitable. Consequently, being a patently plant-based culture, most of Bali's traditional knowledge will certainly be lost unless it is recorded. In order to prevent the degradation of plant resources in Bali, especially with regard to the sustainable existence of the indigenous communities, it is essential to achieve a balance between the exploitation and conservation of resources. It is fundamental to make this a priority in local education from elementary to high

school and beyond before it is too late. For example, the initiative in the Bali Botanic Garden appears to be a good step towards the conservation of both plants and buildings, and ultimately, of Balinese culture.

The people of Bali appreciates plant resources as the basis of their life. Plants provide them with food, medicines, raw materials for construction, manufacture of crafts and tools, and many products including fuel, paints, and cultural products. In Bali, plants definitely have a ritual and cultural character. In a much broader scope, interactions between people and plants can be perceived in ecological perspectives, hence under the study of ethnoecology.

We compiled, extracted, and synthesized data and information contained in published and unpublished reports, complemented with personal field notes of the authors. We wrote the book with the following objectives: (1) providing comprehensive basic information for initial identification of vegetation for students, scientists, and public at large who are interested in identifying various vegetation types; (2) encouraging and enhancing further research on the ecology of vegetation; (3) providing information to be used in biodiversity, conservation and environmental education, in activities of nature lovers, and in ecosystem-based programs of tourism; and (4) providing basic data and information that can be used by decision and policy makers for management and utilization of biodiversity for economic development and people welfare within the context of sustainable and conservation perspectives. Although there are many shortcomings in this book, we believe that description of natural vegetation and the ethnobotany of Bali contained therein are scientifically acceptable. Criticisms and additional information provided by readers will enrich the values of the book.

Geography and Climate of Bali

A. Geography

The official record of the Statistics Indonesia 'Badan Pusat Statistik Provinsi Bali' (Badan Pusat Statistik, 2020) indicates that the Province of Bali covers land and sea with the total area of 5,780.06 km^2 or 0.29% of the entire area of the Indonesian Archipelago. Administratively, it comprises eight *Kabupaten* (regencies) and one *Kota* (city). Geographically, it lies at 114°25'53"-115°42'40" East and 8°3'40"-8°50'48" South, bordered by Strait of Bali on the West, Strait of Lombok on the East, Bali Sea on the North, and Indian Ocean on the South. The land area includes Mount Agung Volcano as the highest point at 3,148 masl (meter above sea level) (Heim, 2015). Other high mountains with the summits of > 1,000 masl are Mount Batukaru (2,276 masl), Mount Abang (2,151 masl), Mount Catur (2,096 masl), Mount Sangyang (2,087 masl), Mount Pohen (2,063 m), Mount Tapak (1,909 masl), and Mount Batur (1,717 masl).

Bali is located within the Cenozoic geological tectonic region of SE Asia and the SW Pacific, and belongs to the Sundaland of the Eurasia continental shelf, in which subduction took place (Hall, 2002). The subduction of the Indian Ocean-Australian tectonic plate under the rigid Eurasian plate at the Java trench (Heim, 2015) caused the formation of

fissures on the surface, resulting in the development of a row of mountains stretching across the island. This mountain range squeezed against the Indian Ocean-Australian plate to the south, triggering volcanic eruptions (Haer et al., 2001; Heim, 2015). The ocean floor, composed of ancient marine deposits, including layers of Tertiary limestone, was lifted above the sea level by the subduction and can be found in some areas, including the huge limestone cliffs of Uluwatu at the Bukit peninsula and at Prapat Agung (Haer et al., 2001).

The geological maps of the Bali Island (Purbo-Hadiwijoyo, 1971; Purbo-Hadiwijoyo et al., 1998) reveals that various formations cover the island, including (1) the Ulakan formation of the Early Miocene period, consisting of breccias, lavas, tuffs, with intercalation of calcareous materials at the Ulakan area in the southeast; (2) Surga formation of Middle Miocene period, consisting of tuffs marls and sandstones occupying a small area along the Surga River watershed; (3) South formation of Miopliocene, consisting predominantly of limestones at Uluwatu and Nusa Penida; (4) Prapat Agung formation of the Pliocene period, consisting of limestones, calcareous materials and sandstones at Prapatagung in the northwest; (5) Asah formation of the Pliocene period, consisting of lavas, breccias, pumiceous tuffs with calcareous cracks fillings, spreading from the northwest of Seririt to the east up to the Norwest Tejakula; (6) Palasari formation of Early Quaternary period, consisting of conglomerates, sandstones, and reef-limestones, extending along the southwest in the Jembrana Regency; (7) Jembrana volcanics formation of the Lower Quaternary period, dominated by volcanic deposits, including lavas, breccias and tuffs which in the mountain region of Jembrana Regency (8) Volcanic deposits formation of the Quaternary period, consisting of tuff and lava deposits of Buyan-Beratan and Batur, volcanic deposits of Mt. Batur, Mt. Agung, Mt. Batukaru, Mt. Pawon,

Mt. Pohen, Mt. Sangiang, and Mt. Lesung, of which only Mt. Agung and Mt. Batur are still active; they occupy the central to eastern section of Bali.

Dalton (2013) described that the Mt. Batur caldera was formed by a huge volcano in ancient times. The volcano was blocked up with huge amounts of magma amassing below the vent hole. When the mountain erupted, the surrounding rocks and land disintegrated into the hole, forming a giant steep-walled crater that looked like a magnificent valley with flat ground. Active volcanism characterizes Bali as shown by frequent eruptions of Mt. Agung as the product of the subduction (Heim, 2015).

Volcanic activities impacted the landscape of Bali and are said to be leading to the formation of many wedge-shaped small kingdoms bordered by daunting mountain barriers and thus prevented the intrusion of foreign cultures (Dalton, 2013). Geologically, these activities led to the mountainous topography and alluvial flats as the results of the eruptions of, for instance, Mt. Batukaru, Mt. Abang, Mt. Batur, and Mt. Agung. Crater lakes were also created and formed the headwaters of many rivers, whose flows eroded their banks, forming gaps, ravines, and valleys. The geological impact and climatic conditions resulted there from a cultural phenomenon is reflected in the utilization of materials for building houses and other structures as well as in agricultural practices (Dalton, 2013).

Haer et al. (2001) noted that because of the intense volcanic activities most of the surfaces of the island have been covered by volcanic materials. Most of the central part of the island is covered by young volcanic deposits of less than one million years old, while elsewhere some deposits are older than one million years. Some very recent volcanic deposits produced by the disastrous Mount Agung eruption in 1963 can be found in the northeast. Dalton (2013) de-

scribed that the powerful eruption of Mount Agung, despite unfortunately killing 1,500 people and destroying hundreds of hectares of valuable farmland, the ejected volcanic rocks provided abundant raw materials for building industries as well as stone carving. He indicated that the thick deposits of fertile ash derived from volcanic eruptions dispersed throughout the entire island by means of irrigation systems, making the island agriculturally productive. The six mountains in Bali with the peaks of more than 2,000 masl created abundant rainfall, resulted from cool moisture-laden winds that were pushed up the slopes. Heavy rainfall caused the swelling of rivers, running down from the highlands through deep narrow gorges and valleys to the extremely rich coastal plain of south Bali.

Dalton (2013) further indicated that Bali has 460 km coastline consisting of mostly rugged beaches and small percentage of sandy beaches, such as those found at Sanur, Nusa Dua, Kuta, Uluwatu, and Tanjung Benoa. Elsewhere beaches consist of black sand, which is the product of violent geological processes, where the hot lava cooled very quickly when in contacts with water and broke down into small debris forming black sand. Tertiary limestone layers that were lifted from the ocean floor can be found in some areas, including high limestone cliffs in Uluwatu at the Bukit Peninsula (Dalton, 2013).

Useful information on the geology of Bali can be extracted from the Bali-Nusa Tenggara Ecoregion scheme of Ministry of Environment (2013). Geology was presented briefly as one of the parameters along with others, including geomorphology, morphogenesis, soils, and climate, to characterize ecoregion units: (1) Marine flat plain, an area composed of marine alluvial sediments and spreads in the region at the edge of then marine area, especially at the

ring of fire tectonic zone; (2) Fluvial flat plain, consisted of non-marine all fluvial materials from the terrestrial land in the region of the tectonic zone in front and at the back of the ring of fire arc; (3) Organic/coral flat plain, composed of coral limestone in the tectonic zone in front and at the back of the ring of fire arc; (4) Volcanic flat plain area, consisted of volcanic products, including igneous and pyroclastic rocks, distributed around the volcanic hills and mountains in the tectonic ring of fire zone; (5) Solutional limestone hills region, composed of limnestones, including karst landform, distributed in flat plain and hilly areas on the outer tectonic ring of fire zone; (6) Volcanic hills region, consisted of volcanic products or pyroclastic sediments and igneous rocks, distributed in hilly areas on the outer tectonic ring of fire zone; and (7) Volcanic mountains region, consisted of volcanic products or pyroclastic sedimentary and igneous rocks, distributed in the mountainous region in the tectonic ring of fire zone.

The distribution and characteristics of the soils of Bali showed marked variations. They were closely correlated with the distribution of the volcanic deposits derived from the Batur volcanic eruption, taking place about 23,700 years ago, which affected the regional hydrology (Tanaka & Sunarta, 1994). The thick deposits of ashes, resulted from volcanic activities generated soil fertility, have been a strong factor in the agricultural prosperity of the island (Haer et al., 2001; Dalton, 2013).

Taking into consideration a set of characters, including the geomorphology and morphogenesis, in the Bali-Nusa Tenggara Ecoregion scheme, Ministry of Environment (2013) presented briefly the soils of Bali in the context of the following ecoregion units:

1) Marine flat plain (*Dataran marin*), hydromorphic soils with high fertility and high salinity resulted from direct influence of sea water and regosol with low fertility because of the rough texture as a consequence of marine alluvial processes. Included in this group are soils in mangrove and coastal areas on land with flat to undulating topography at the elevation of < 25 masl. It occurs on the western and southern sections of Bali.
2) Fluvial flat plain (*Dataran fluvial*), dominated by hydromorphic alluvial soils having rich nutrients but constrained by poor drainage. Other soil types including grumusols with high fertility but structurally muddy in wet season and cracked in dry period, occurred also in places. They can be found in the northern and southern regions of the island.
3) Organic/coral flat plain (*Dataran organik/koral*), dominated by shallow litosol soil with low fertility and composed of organic materials derived from uplifted coral reef limestones previously submerged in the shallow water. Another soil type found was regosol with coarse texture and low fertility. These soils types occurred in the eastern section of Bali.
4) Volcanic flat plain (*Dataran vulkanik*), consisted of latosol with high fertility, derived from volcanic materials. It occurred in the northern and southern sections of Bali, on flat to undulating topography and slopes with elevation < 300 masl.
5) Solutional limestone and karst landform hills (*Perbukitan solusional/karst*), consisted of limestone uplifted from the shallow sea bottom by tectonic activities and occurred in the seasonally dry monsoon areas in southern and eastern region of Bali with elevation of < 500 masl and undulating topography. The dominant soil is terra

rosa, a red soil, and the shallow litosol soil developed from slowly weathering limestone, with low acidity and fertility.

6) Volcanic hills (*Perbukitan vulkanik*), consisting of deep latosol soil with low to high fertility deriving from old volcanic tuff. Other soil types included structurally coarse and heavy Mediterranean soils with medium fertility. They occurred mostly on hills with elevation of < 500 masl in the western, central, and northern regions of Bali.
7) Volcanic mountains (*Pegunungan vulkanik*), dominated by andosol and latosol soils derived from the volcanic materials, with high fertility occurring on slopes in mountainous areas. Grey regosol soil deriving from volcanic eruptions having high fertility can also be found along rivers and upper slopes. They all occurred in central and northern sections of Bali at elevation > 500 masl.

The above account may be complemented with the map prepared by Macklin (2019) on the distribution of 13 soil types occurring on Bali, which are narratively and briefly described as follows. The yellowish-brown latosol covered the largest area in the central part of Bali almost one third of the island, extending from the north to the south, broken only by the grey-brown andosol and the grey regosol in the mountain areas. The next largest area was covered by brown latosol and litosol in the entire Jembrana Regency and almost half of the Buleleng Regency in the west and the eastern tip of the island at Karangasem. The grey regosol occupied the third largest extent at the Karangasem Regency and small mountainous areas at regencies of Buleleng, Badung, and Tabanan. The yellowish brown regosol covered about three quarters of the Gianyar Regency and

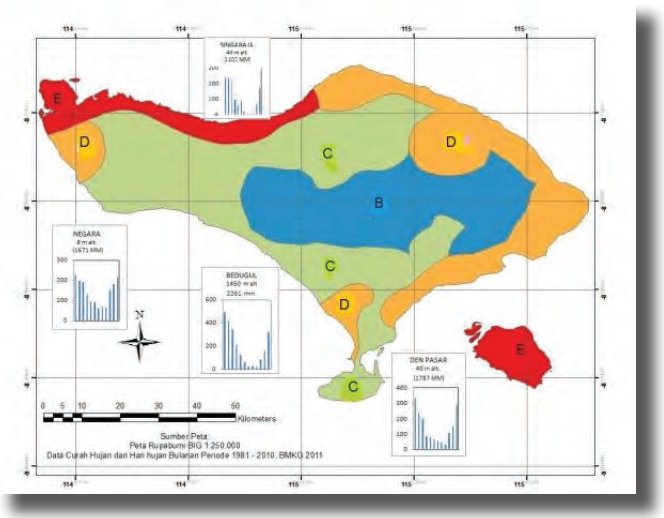
small sections of Karangasem and Bangli Regencies. Humic regosol occurred in about two third of the Bangli Regency and about one quarter of the Gianyar Regency in the north. Brown regosol can be found along the coastal areas in the eastern region and the western tip of the Buleleng Regency. Reddish brown latosol and litosol occurred in the southern Karangasem Regency. Grey brown regosol can be found in the north coastal area of the central section of the Buleleng Regency. The reddish brown Mediterranean dominated the entire Nusa Dua peninsula in the Badung Regency and the Nusa Penida Island in the Klungkung Regency. Other soil types occurring in Bali in smaller areas or patches included the grey brown alluvial, hydromorphic alluvial, grey brown andosol, yellowish brown latosol, brown Mediterranean and humic regosol soils.

B. Climate

In a very extensive area, vegetation units and patterns may be similar. However, the physiognomy, structural and functional characteristics of a vegetation often depend on regional climate, geomorphology, and soils as the substrate, and the disturbance factor of a region (Mueller-Dombois & Fosberg, 1998). Regarding the climatic aspect, the rainfall component is very prominent that the climatic types can be frequently expressed as the rainfall types, as has been used by Schmidt and Ferguson (1951). For Bali it is shown in Figure 2.1 and Table 2.1.

Mean monthly rainfalls at Bedugul, Denpasar, Negara and Singaraja based on normal data with information for each type is described in Table 2.1.

The above climate classification system has been applied widely in Indonesia, including Bali, and even used by Whitmore (1986) for Southeast Asia. The system uses index Q



Source: Berlage (1949); Badan Meteorologi Klimatologi dan Geofisika (2010)

Figure 2.1. Rainfall types in Bali according to Schmidt and Ferguson (1951).

($Q = \frac{\text{number of dry months}}{\text{number of wet months}} X\ 100\%$) to characterize rainfall type. In Bali, four rainfall types can be recognized (Figure 2.1; Table 2.1). Type B (humid) covers the central part of the island, type C (slightly seasonal) is dominant, covering the western, northern, and southern sections of Bali, type D (seasonal) is prevalent in the north-eastern and southern coastal, as well as low-lying areas and a small patch in the western region, and type E (strongly seasonal) extends on the north-western coastal region of the island and the Nusa Penida Island. This region experiences seasonal slight dry to extremely drought climate with the mean monthly rainfall of less than 100 mm over a short to long period of time, hence the evapotranspiration during this period exceed the rainfall resulting in shortage of water available to plants, where in the extremely dry climate (Type E) plants are deciduous during this period.

Table 2.1 Description of rainfall types in Bali according to Schmidt and Ferguson

Type	Q	Description
B	14.3–33.3	Humid. Natural vegetation: everwet and evergreen rain forest, largely has been converted into man-made forest, cultivated land (rice fields, gardens) and settlements
C	33.3–60.0	Slightly seasonal. Natural vegetation: slightly seasonal lowland evergreen rain forest, largely has been converted into man-made forest, cultivated land (rice fields, gardens) and settlements
D	60.0–100.0	Seasonal. Natural vegetation: seasonal, evergreen lowland forest, largely has been converted into man-made forest, cultivated land (rice fields, gardens) and settlements
E	100.0–167.0	Strongly seasonal. Natural vegetation: seasonal deciduous lowland forest and savanna, largely have been converted into man-made forest, cultivated land (gardens) and settlements

Source: Schmidt and Ferguson (1951)

As a whole, the rainfall pattern in Bali is seasonal. Seasonal variation is attributed to wet wind blowing from the north resulting in wet season with high rainfalls from October to March, and the dry wind blowing from the east and south east resulting in the dry season from June to August. Such rainfall patterns affect the seasonal availability of water to plants leading to the variation of vegetation types.

Vegetation of Bali

A. Flora and Plant Geography

Morin (1989) defined the term flora as plant species occurring in a certain region and referred also to a publication describing the plant species of that region. To avoid a confusion, the first letter of the term flora is written in capital letter, thus Flora, if we refer to the publication and this has been adopted as a convention. As indicated earlier flora should not be confused with vegetation, which is a mosaic of plant communities in a landscape (Küchler, 1967) or in a geographic region (Walter, 1971) without taking environmental factors into consideration. Although the flora and vegetation constitute two different concept, it should be noted that flora is the main component and the basic foundation of a vegetation (Mueller-Dombois & Fosberg, 1998).

Plant distribution over an extensive area is defined as plant geography or phytogeography. In phytogeography, complexity and diversity is high, and discrete boundaries are often unclear, thus forming a continuum (Mueller-Dombois & Fosberg, 1998). It is further complicated by the fact that floristic data are frequently incomplete. In Indonesia, information and detailed narrative account may be obtained from the Flora Malesiana Serie I, Volume 1–23 (Steenis et al., 1951–2019) and for Java from Flora of Java 1–3 (Backer & Bakhuizen van den Brink, 1963, 1965, 1968).

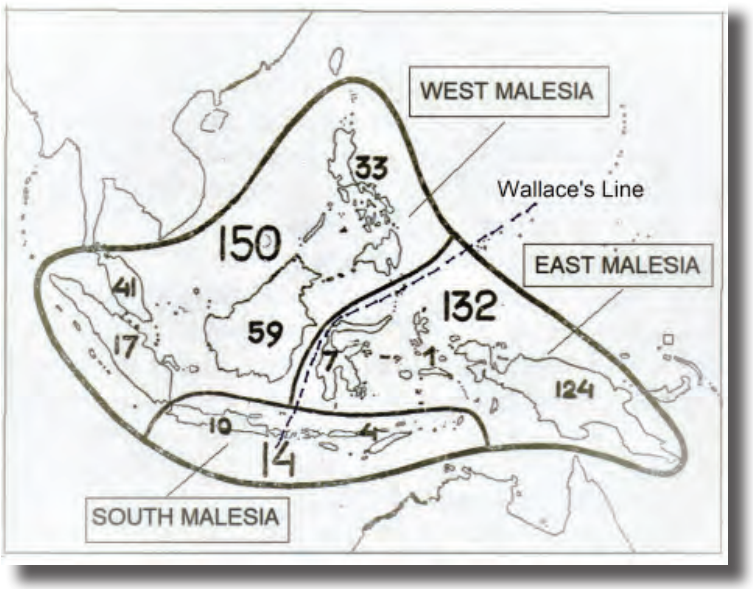
To describe a plant geographic distribution at the species level with clear boundaries is not an easy task, but at the generic level geographic distribution with clear boundaries can be quantitatively and easily defined (Steenis, 1950). On the basis of this scheme, Steenis (1950) established the phytogeography region of Malesia, covering Brunei Darussalam, Indonesia, Malaysia, Papua New Guinea, Philippines, Singapore, and Timor Leste. The boundaries of Malesia were defined based on tactical phytogeography research leading to the creation of three important boundaries (Figure 3.1). Analysis of geographic distribution at a generic level (Steenis, 1950) showed that distribution of 40% of genera have distribution restricted to and centered in Malesia, 27% of genera are distributed in Asia, Australia, and Malesia, and 26% of the genera are centered in Asia and not found in Australia. In view of these facts, the phytogeography region of Malesia can be proclaimed as an independent phytogeography unit at the same level as the South East Asian phytogeography region. In this context the 40% of genera in Malesia are endemic genera and are not found elsewhere outside this region.

The Malesian region can be further subdivided into smaller phytogeography provinces (Figure 3.1): (1) West Malesia comprising the Peninsular Malaysia, Sumatra, Borneo, and the Philippines; (2) East Malesia, covering Sulawesi, Maluku, and New Guinea; and (3) South Malesia, consisting of Java, Madura, Bali, Nusa Tenggara, and Timor Leste. As indicated earlier, the South Malesian Province is floristically poorer compared to West and East Malesia, respectively, and is poor in the number of endemic genera and species (Steenis, 1950; Kalkman, 1955). Parts of the South Malesia Province coincides with region having seasonally dry monsoon climate, dominated by seasonally dry forests

and savannas. In Java, there is a distinct correlation between certain plant species distribution and the seasonal dry climatic conditions (Steenis & Schippers-Lammertse, 1965), which is assumed to hold true in Bali and other islands in Nusa Tenggara, but to date no such observation has been conducted.

The border between West Malesia and East Malesia coincides with the Walllace Line. The Wallace's Line divides faintly the flora of West and East Malesia, although the occurrence of some taxa are mostly concentrated to West Malesia, such as *Dipterocarpaceae*, *Schima wallichii*, and *Altingia excelsa*, while others to East Malesia, including *Araucaria* spp., *Elmerillia* spp., *Koordersiodendron* spp., and *Nothofagus* spp. (Whitmore, 1986). *Schima wallichii* and *Altingia excelsa* are present in Bali (Girmasyah et al., 2013).

Although Bali and East Java have high floristic similarity (Steenis, 1950; Steenis &_Schippers-Lammerstse, 1965), only a few species are present in Bali but not in East Java, moreover, Backer and Bakhuizen van den Brink (1965) excluded Flora of Bali from the Flora of Java. The Flora of Java and Nusa Tenggara, including Bali, is characteristically poor in species and low in endemic genera (Steenis, 1950). Java and Nusa Tenggara jointly constitute a separate province of Malesia (Steenis, 1950). Compared to the other islands in the Nusa Tenggara, collection of herbarium specimens from Bali is remarkably poorer, due to the prohibition of collecting plant specimens during the 19th Century and early 20th Century (Girmansyah et al., 2013). Consequently, efforts to write a Flora of Bali has been constrained by the inadequacy of the herbarium specimens, and to date by far only a checklist has been produced (Girmansyah et al., 2013).



Source: Kartawinata (2013)

Figure 3.1 Number of Endemic Genera of Flowering Plants in West Malesia, East Malesia and South Malesia Provinces and the Wallace' Line (after Steenis 1950, with labels and Wallace's Line added)

Flora of Malesia is rich, of which 40% of the genera are endemic (Steenis, 1950). Largest families include *Orchidaceae*, where in Java alone 731 species have been recorded (Comber, 1990), while in Bali Girmansyah et al. (2013) registered 147 species. Among the woody species, *Dipterocarpaceae* is one of the most prominent families containing 386 species (Ashton, 1982), whose distribution are concentrated to West Malesia, while in Bali there are only three species, i.e. *Dipterocarpus hasseltii*, *Dipterocarpus retusus* and *Hopea sangal* (Ashton, 1982, Girmansyah et al. 2013). Big genera of flowering plants occurring in Malesia include *Ficus* (*Moraceae*) which contains 367 species (Berg & Corner, 2005) and 22 in Bali; *Rhododendron* (*Ericaceae*)

has 287 species (Sleumer, 1966), and only three species respectively can be found in Bali (Girmansyah et al., 2013).

In East Malesia, conifers, in particular *Agathis celebica*, *Agathis robusta*, *Agathis labillardieri*, *Araucaria cunninghamii* var. *papuana*, and *Araucaria hunsteinii* (de Laubenfels, 1988) are more prominent compared to *Dipterocarpaceae*. De Laubenfels (1988) recorded five families and 75 species occurring in Malesia, distributed mainly in the mountainous regions at 1,000-3,800 masl. Of this number, 21 species can be found and prevalent only in East Malesia. In Bali, only *Dacrycarpus imbricatus* and *Podocarpus neriifolius* have been recorded (Girmansyah et al., 2013).

Among herbs, beside *Orchidaceae*, the big family includes *Cyperaceae* and *Poaceae*. Many species of *Cyperaceae* constitute dominant and important component in various herbaceous communities spreading from coastal areas to the tops of mountains in Indonesia. There are 4,000 species distributed throughout the world (Kern, 1974), and yet there are only 23 species occurring in Bali (Girmansyah et al., 2013). *Poaceae*, whose species, except bamboos, cover large areas of low stature grass vegetation from coastal areas to mountain tops, has the total number of species of 9,500 worldwide (Mabberley, 1997), and only 163 species existed in Bali (Girmansyah et al., 2013).

The geological events took place during the Tertiary and Quaternary periods have affected the existence and geographic distribution of flora, vegetation, and fauna. Whitmore (1981, 1986, 1990) briefly described the main geological event, affecting the biogeography in Malesia that was the progressive splitting of the southern continent Gondwana about 140 million years ago. The Indian fragment moved to the north and collided the northern continent Laurasia about 55 million years ago, and the fragment of Australia/New Guinea collided with the southeastern tip of Laurasia

at Sulawesi during the Middle Miocene atf about 15 million years ago. Therefore, the Sunda region is the part of the Laurasia and the Sahul region constitute the part of Gondwana. The flowering plants were assumed to have started developing at the time the Gondwanaland began to split (Whitmore, 1986). Plants and animals reached the Malesian region without crossing one of the Laurasia routes, Gondwana route through Australia, or Gondwana route passing through India, followed by migration to the southeast. In addition, some groups were autochthonous that developed at the original sites as found today. Wallace's Line is one of the strongest and most dramatic zoogeographic boundaries existing in the world, signifying contact zones between Laurasia and Gondwana fauna, though it is not a strong boundary for phytogeography compared to that of zoogeography. However there are several taxa centered in the Sundaland, including *Artocarpus*, *Pinus*, and *Dipoterocarpaceae*, while others centered and dominant in Gondwana region, such as conifers (except *Pinus*) (Whitmore, 1986). Kalkman (1955) noted a progressive decrease of occurrence of certain species from east to west, as exemplified by *Eucalyptus* species, which are dominant species in Australia but less prevalent in the west, Papua, Sulawesi, and Nusa Tenggara. In Bali, not a single species is occurring naturally and the 10 species found there all are cultivated.

The paleoclimatic and vegetation history of Malesia has been described by Flenley (1979), Maloney (1980), and Whitmore (1981). It was noted that there were factual proofs that the Quaternary Glacial period in the northern latitude of the tropical region constitute the drier seasonal period. The sea level was 180 m lower because a very large quantity of water was stored in the form of ice in the region now known as the region with temperate climate. Global cooling affected the tropical montane regions, pressing the

permanent snow level and the tree-line. Cooling by about 10°C occurred in the montane region but only 2-3° C at the sea level, montane zones were compressed. Climatic fluctuation took place continuously in line with the Glacial and Interglacial periods. The present climate of Malesia is as warm and wet as any time during the Quaternary period. Sea level from time to time rose to 3-7 m higher than at present. During the time when the sea level was 180 m lower than at present, the area of the Sunda Shelf exposed was twice as big. During the period of lower sea level and the climate was more seasonal, two big blocks of rain forests were shrinking with the occurrence of more extensive seasonal forests and savannas in the intervening region and probably extensive in the continental shelf together perhaps with extensive mangroves and swamp forests. Forest clear cutting by people in Sumatra took place 7,500 years ago and in New Guinea 9,000 years ago (Flenley, 1979).

B. Vegetation Classification

In Bali we can record natural vegetation and man-made vegetation. In the present vegetation classification, we are concerned only with the natural vegetation. Natural vegetation is a mosaic of plant communities within a landscape undisturbed by human activities. It has adapted to its environment, hence it is present in a harmonious relationship with other elements of the landscape. Natural vegetation does not only constitutes a component of biodiversity providing biological resources, but also bears important functions in hydrology and climate improvement. Currently natural vegetation occurs primarily in the mountain region, while in the lowland area it has been mostly converted into man-made vegetation (gardens, rice fields, forest plantation) and human settlements. Whitten et al. (1996) noted that by 1996, the natural forest area covered only 1,009 km^2 or 18.1%

of the total area of Bali (5,780.06 km^2) and the remainders consisted of scrubs (633 km^2), gardens (54 km^2), permanent upland cultivation (1,309 km^2), wet rice fields (1,082 km^2), tree crops and estates (972 km^2), water (35 km^2), and settlements (320 km^2).

In addition to the established natural vegetation, developing natural primary and secondary successional vegetation, may also be encountered in Bali. A primary successional vegetation developed on new substrates formed by landslides and layers of ash, sand, and lava deposited by volcanic eruptions, such as the vegetation developed after Mt. Agung eruption in 1963 (Dilmy, 1965). The secondary successional vegetation developed on old substrates, whose original vegetation covers have been destroyed by human activities, such as clear-cut forests, fallowed shifting cultivation lands, abandoned agricultural lands, and any lands left unattended; the so called scrubs mentioned by Whitten et al. (1996) may be referred to this category.

Vegetation can be classified into different types using different approaches. Vegetation classification is in essence hierarchical and the highest level is the division of world vegetation into identifiable physiognomic category, i.e. biome, which cannot be identified using species composition (Deshmukh, 1992). In the tropics, several terrestrial biomes can be identified, such as rain forest biome, monsoon forest biome, savanna biome, dwarf forest biome, thorny scrub biome, and grassland biome (Whittaker, 1970). A low level classification of a terrestrial biome can be made on the basis of temperature and rainfall (Whittaker, 1970). The climatic variable may be further divided in more details and even integrated with the elevation factor (Steenis, 1975; Whitmore, 1986).

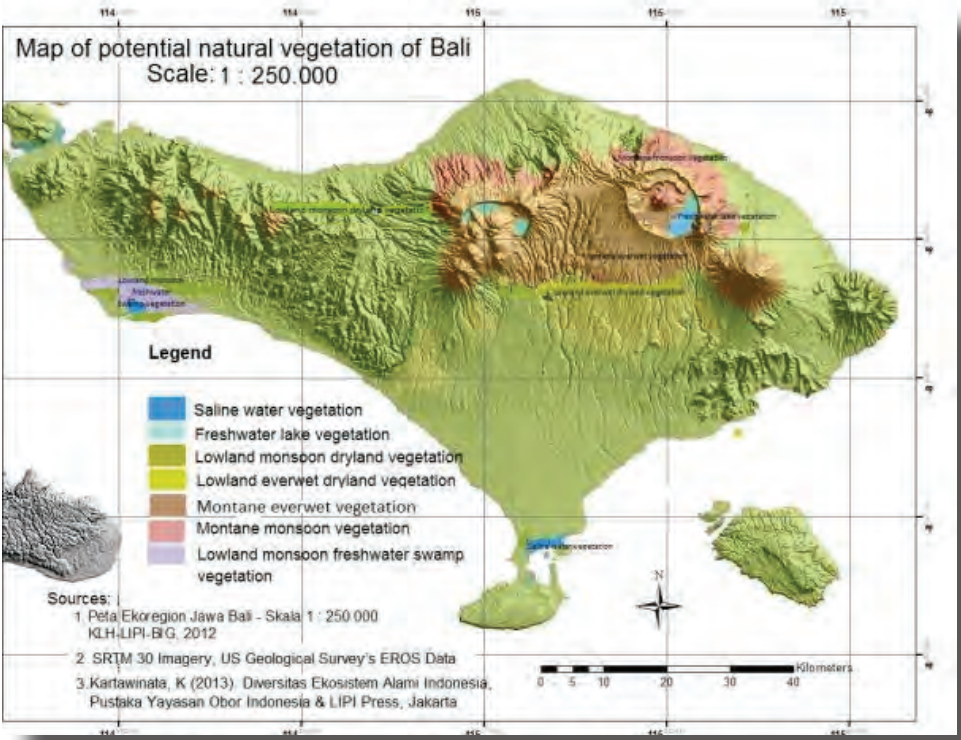
The term vegetation type is used as a term to express a widespread group of species. This concept has been ap-

plied to Indonesia (Kartawinata, 2005, 2013), which in the following account is further adapted to Bali and each type is further described in details based on floristic composition and habitat (Table 3.1; Figure 3.2). One community type or more characterize(s) a landscape or a region. The largest number of community types can be found in an extensive rain forest having high diversity of species and habitats. Steenis (1957) used habitat factor as the foundation to outline floristic and vegetation zones in Malesia, which was later adopted also by Whitmore (1986). This outline was used in the plant geographic description in Java (Steenis & Schippers-Lammerste, 1965). Kartawinata (2005) refined the scheme further and applied it to Indonesia, and the latest version is presented in Kartawinata (2013) along with brief descriptions of all vegetation types, which in turn was used to identify natural ecosystem types in Indonesia.

Table 3.1 Outline of Vegetation Types in Bali

CLIMATE (RAINFALL TYPE)	ELEVATION	WATER STATUS	SOIL	VEGETATION TYPE
I. Everwet Q= 13.3 - 33.3 (Type B); Mean annual rainfall 1,000 – 7,100 mm	Highland/ mountain (750) 1,000 – 3,000 masl	Dry land	Red Yellow Podsolic, Latosol, Andosol, Lithosol; Dry	1. Montane evergreen forest

CLIMATE (RAIN-FALL TYPE)	ELEVATION	WATER STATUS	SOIL	VEGETATION TYPE
II. Seasonally Short to Long Dry Monsoon Q = 33.3 - 300 (Type C, D, E) Mean annual rainfall: 700-2,900 mm	Lowland 0 – 1,000 masl	Saline water	Coral and sand; Wet Alluvial; Wet	2. Vegetation on saline water 2.1. Monsoon littoral vegetation 2.2. Monsoon mangrove forest
		Stagnant fresh water	Alluvial; Wet	3. Fresh water swamp monsoon vegetation 3.1 Fresh water monsoon herbaceous vegetation 3.2 Fresh water monsoon swamp forest
		Dry land	Regosol; Dry Red Yellow Podsolic, Latosol; Dry Podsol; Dry Rendzina Latosol; Dry Ditto Ditto Ditto	4. Dry land vegetation 4.1 Sandy and/or rocky beach monsoon herbaceous vegetation 4.2 Sandy and/ or rocky coastal monsoon forest/ Lowland seasonal deciduous monsoon forest 4.3 Lowland evergreen monsoon forest 4.4 Monsoon scrub 4.5 Monsoon savanna 4.6 Monsoon grassland



Source: Kartawinata (2013)

Source: Ministry of Environment and Forestry of the Republic of Indonesia (2018)

Figure 3.2 Map of generalized potential natural vegetation on Bali; much of the lowland vegetation has been converted into agricultural lands, settlements and tourist areas.

C. Vegetation Type

Various vegetation types are located in Bali, ranging from everwet to seasonally dry vegetation types, extending from submerged coastal areas to the mountain tops. The distribution of everwet vegetation types coincides with the range of Schmidt and Ferguson's rainfall types B (Figure 2.1). The average monthly rainfall is greater than 100 mm,

hence the area is always wet throughout the year without any pronounced dry period. The seasonally dry vegetation types distribute throughout the range of the Schmidt and Ferguson's rainfall types C-E (Figure 2.1) and are confined to the lowland area, with the elevation of 0–1,000 masl. The average monthly rainfall of less than 100 mm over a short to long period of time, hence the evapotranspiration during this period exceeds the rainfall, resulting in shortage of water available to plants. The number of rain days in four consecutive four driest months is < 20. Short to very long dry seasons occur in the middle of the year. Monsoon or seasonal vegetation, comprising monsoon forest, savanna, and grassland, occurs in regions experiencing seasonal climate with slight to pronounced alternating dry and wet periods. Monsoon forest occur at the altitude of 0–800 m (Whitten et al., 1996; Monk et al., 1997).

D. Littoral Vegetation

This vegetation type together with the mangrove vegetation type belong to the saline water vegetation, where substrates are permanently flooded with saline water. The littoral vegetation generally developed in the sandy or rocky coastal areas with shallow saline water, not affected by big rivers and can be found also between steep rocky walls (Kartawinata & Soemodihardjo, 1977). In the first instance, the coast can extend far seaward ending at the fringing reefs. The vegetation on shallow waters near the coasts is usually dominated by sea grass and algae. The sea grass species in the communities consist of *Cymodocea serrulata*, *Enhalus acoroides*, *Halodule pinifolia*, *Halodule uninervis*, *Halophila ovalis*, and *Thalassia hemprichii* (Monk et al., 1997). Local distribution shows that *Thalassia hemprichii* and *Halophila ovalis* developed in shallow waters close to the coastline (Steenis, 1957), while *Enhalus acoroides* and *Halodule unin-*

ervis occur on deeper sites seaward. It is common that they form pure communities.

Along the Sanur beach, Arthana (2005) recorded the following species: *Enhalus acoroides*, *Cymodocea rotundata*, *Cymodocea serrulata*, *Halophila ovalis*, *Halodule pinifolia*, *Halodule uninervis*, and *Syringodium isoetifolium*. The dominant species was *Enhalus acoroides*, its density ranged from 40 to 338 per 0.55 m^2, which was related to the water depth, where the highest was found in the middle of lagoons. Coral reefs that are included in the littoral vegetation are the product of a variety of organisms, particularly Coelenterata. Other species, such as worms, mollusks, and calcareous algae (*Halimeda*, *Lithothamnum*) play important roles also in the coral reef formation. Rocky shores inhabited by various communities of algal species may also be encountered along the coast.

In West Nusa Tenggara, which is likely so in Bali, algal communities form zones. The algal communities in the shallow water habitats consist of species of *Gracillaria*, *Halimeda*, *Padina*, and *Sargassum*. Communities on sandy and rocky coastal flats near the beach are dominated by species of *Bodlea*, *Chaetomorpha*, *Gracilaria*, and *Hypnea*, while the middle sections of coral reef flats the communities are dominated by species of *Padina* and *Halimeda*, and at the edge of the coral reef flats species of *Acanthophora*, *Bodlea*, *Chaetomorpha*, *Gracilaria*, *Laurensia*, and *Turbinaria* dominate the communities (Monk et al., 1996).

E. Mangrove Forest

Mangrove forests along with nipah (*Nypa fruticans*) community and herbaceous *Acrostichum aureum* community are often referred to as tidal and saline swamp forest. Largest area of the mangrove forests in Indonesia occurs in Papua, Kalimantan, and Sumatra. Bali covers only a small area, and

the largest areas can be found at the Ngurah Rai Forest Park (1,373.5 ha) in Tanjung Benoa and Serangan Island, West Bali National Park (602 ha), and Nusa Lembongan (202 ha) (Widagti et al., 2011). Species composition and structure of mangrove forests vary according to habitat conditions, ranging from dwarf and sparse communities consisting of one species (*Rhizophora stylosa*) growing on coral reefs (Budiman et al., 1986) to mixed tall and dense forest growing on deep mud. Freshwater supply, which affects salinity, nature of substrate, and pattern of tidal movement related to frequency of inundation, are factors attributing to vegetation zone formation. On more solid and firm mud a palm species, N*ypa fruticans*, is usually dominant. On open and dry substrates, species of sedge family may be encountered, including *Fimbristylis argentea*, *Fimbristylis politrichoides* (often very abundant), and *Cyperus javanicus* (Kern, 1974).

Species richness in mangrove forests is low. The total number of species in Indonesia was only 95 species, in which 40 are tree species (Kartawinata et al., 1979). In Bali the following mangrove species have been recorded (Noerdjito et al., 2011; Roemantyo, 2011; Girmansyah et al., 2013), i.e. *Aegiceras corniculatum*, *Aegiceras floridum*, *Avicennia marina*, *Avicennia officinalis*, *Bruguiera cyllindrica*, *Bruguiera gymnorrhiza*, *Bruguiera sexangula*, *Cerbera manghas*, *Ceriops australis*, *Ceriops decandra*, *Ceriops tagal*, *Dolichandrone spathacea*, *Excoecaria agallocha*, *Heritiera littoralis*, *Hibiscus tiliaceus*, *Lumnitzera littorea*, *Lumnitzera racemosa*, *Nypa fruticans*, *Pongamia pinnata*, *Rhizophora apiculata*, *Rhizophora lamarckii*, *Rhizophora mucronata*, *Rhizophora stylosa*, *Scyphiphora hydrophylacea*, *Sonneratia alba*, *Sonneratia caseolaris*, *Terminalia catappa*, *Thespesia populnea*, *Xylocarpus granatum*, *Xylocarpus moluccensis*, and *Xylocarpus rumphii*.

At the base of Mt. Prapat Agung, Soepadmo (1961) reported that during the dry season the mangrove forest was

dry and trees shed their leaves, unlike mangroves elsewhere which are evergreen. In the interior the forest was dominated by dense *Rhizophora* spp., (particularly the three common species: *Rhizophora apiculata*, *Rhizophora mucronata*, and *Rhizophora stylosa*) and *Xylocarpus moluccensis*.

Mount Prapat Agung is currently included in the West Bali National Park (WBNP). Recent study on the mangrove forests in WBNP was carried out by Arinasa (2012). He studied in nine sites distributed westward from Banyuwedang, Telukterima, Brumbun, Kelor, Lampumerah, Batulicin, Prapatagung, Gilimanuk, to Sumbersari. He recorded 18 families, 21 genera, and 28 species or 11.5% of the total number of mangrove species of Indonesia. Those included *Acanthus ebracteatus*, *Acrostichum aureus*, *Aegiceras floridum*, *Ardisia humilis*, *Avicennia marina*, *Avicennia officinalis*, *Barringtonia asiatica*, *Bruguiera cylindrica*, *Bruguiera gymnorrhiza*, *Cerbera odollam*, *Ceriops australis*, *Ceriops tagal*, *Dolichandrone spathacea*, *Excoecaria agallocha*, *Heritiera littoralis*, *Lumnitzera racemosa*, *Nypa fruticans*, *Osbornia octodonta*, *Pemphis acidula*, *Pongamia pinnata*, *Rhizophora apiculata*, *Rhizophora lamarckii*, *Rhizophora mucronata*, *Rhizophora stylosa*, *Sonneratia alba*, *Thespesia populnea*, *Xylocarpus granatum*, and *Xylocarpus moluccensis*. The family having the highest number of species in WBNP was *Rhizophoraceae* with eight species, followed by *Myrsinaceae* with two species, then *Avicenniaceae* and *Meliaceae* with two species each, while *Acanthaceae*, *Apocynaceae*, *Arecaceae*, *Bignoniaceae*, *Combretaceae*, *Euphorbiaceae*, *Fabaceae*, *Lecythidaceae*, *Lythraceae*, *Malvaceae*, *Myrtaceae*, *Pteridaceae*, *Sonneratiaceae* and *Sterculiaceae* with one species, respectively. Eight species of mangrove species were new records at WNBP, they were *Acanthus ebracteatus*, *Cerbera odollam*, *Dolichandrone spathacea*, *Xylocarpus moluccensis*, *Xylocarpus granatum*, *Aegiceras floridum*, *Heritiera littoralis*, and *Ceriops australis*.

According to the IUCN category, most of the mangrove species found here were listed as species of Least Concern/LC, except for *Aegiceras floridum* which was listed as Near Threatened/NT (IUCN, 2020).

It was noted that the number of species recorded in the nine sites varied, which seemed to be related to the habitat conditions of the sites. The highest number of species (24) was recorded in Gilimanuk and the lowest (5) in Prapat Agung. The species richness tends to change in response to habitat variation, expressed in the form of mangrove forest zonation. Westward from Banyuwedang to Prapat Agung, the habitat mostly consisted of sandy corals, exposed to strong sea waves, allowing only certain species to grow. In the mangrove zone of Banyuwedang, Gilimanuk and Teluk Terima, which were located in the bay, the habitats consited of newly formed mud sediments and firm mud deposits mixed with sand and corals that were exposed to gentle sea waves, thus allowing more species to grow.

Arinasa (2012) classified the mangrove species in WBNP into groups based on their population density: (1) species with low density were *Acanthus ebracteatus*, *Barringtonia asiatica*, *Cerbera odollam, and Nypa fruticans*; (2) species with medium density were *Acrostichum aureum*, *Avicennia officinalis*, *Bruguiera cylindrica*, *Ceriops australis*, *Dolichandrone spathacea*, *Heritiera littoralis*, *Osbornia octodonta*, *Pongamia pinnata*, *Rhizophora lamarckii*, *Rhizophora mucronata*, *Sonneratia alba*, and *Thespesia populnea*; (3) species with high density were *Ardisia humilis*, *Aegiceras floridum*, *Avicennia marina*, *Bruguiera gymnorrhiza*, *Ceriops tagal*, *Excoecaria agallocha*, *Lumitzera racemosa*, *Pemphis acidula*, *Rhizophora apiculata*, *Rhizophora stylosa*, and *Xylocarpus granatum*.

Figures 3.3. and 3.4. show *Rhizophora apiculata* growing in the mangrove forest planted in December 1995 (Juwari et al., 2020) near the Ngurah Rai International Airport. Proisy et al. (2018) study on the revegetation using satellite images

in abandoned aquaculture ponds in Perancak showed trends in the evolution of mangrove forests from 2001 to 2015. Mangroves were expanding inside and outside the ponds. It was noted that only *Rhizophora* species (*Rhizophora apiculata*, *Rhizophora mucronata*, and *Rhizophora stylosa*) had been planted, whereas natural invasion was attributed to natural mangrove species, including *Avicennia* species (*Avicennia alba*, *Avicennia marina* and *Avicennia officinalis*), *Ceriops decandra* and *Sonneratia alba*. The dense planted *Rhizophora* had very low regeneration capabilities compared to naturally invading species, i.e., *Hibiscus tiliaceus* (Figure 3.5)

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.3 Mangrove planted in 1995 near the Ngurah Rai International Airport, Denpasar (above) is dominated by Rhizophora apiculata (below)

Photo: Wawan Sujarwo (2012)

Figure 3.4 *Rhizophora apiculata* is growing in the planted mangrove forest near the Ngurah Rai International Airport

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.5 *Hibiscus tiliaceus* in Fruiting Found in Between the Very Degraded Mangrove and Monsoon Coastal Forests in Banjar Dangin Berawah Desa Perancak, and Desa Air Kuning (Yeh Kuning), Jembrana.

F. Freshwater Swamp Vegetation

Freshwater swamp vegetation forms a continuous stretch from open water to mixed forest, depending on the depth and quality of water, drainage, and conditions of inundation (Paijmans, 1976). A freshwater vegetation occurs on site permanently or seasonally inundated by water deriving from rainfall or back-up water from a river, rich in nutrient with pH ≥ 6 and develops over newly formed alluvial soils (Whitmore, 1986). Kinds of vegetation developed on freshwater habitats vary depending on habitats. Freshwater vegetation occurs throughout Indonesia, on sites with climate ranging from everwet to very dry, from lowland to highland (Steenis, 1935a, 1935b, 1957; Kartawinata, 2013). Species composition varies according to habitats and vegetation types.

Just like any other sites in Indonesia, in Bali we may encounter various freshwater herbaceous vegetation in lakes, ponds, stagnant river levees, or any inundated sites from lowland to highland. They are indicated by the presence of free floating aquatic plants, aquatic plants that are rooting in the mud at the bottom of lakes and ponds. They are distributed from sea level to the mountain tops. Floating aquatic plants often form very dense vegetation, like those formed by *Najas* sp., *Ceratophyllum* sp., *Utricuaria* sp., *Hydrilla* sp. and *Pistia* sp., which sometimes mix with many grass and sedge species. Floating aquatic plants that are rooting on mud at the bottom of inundated lands may form an extensive vegetation, composed of *Nelumbium nelumbo*, *Nymphaea lotus*, *Limnanthemum indicum*, *Ottelia allismoides*, etc. (Figure 3.6) (Steenis, 1935a, 1935b). Sago palm (*Metroxylon sagu*) community may be found scattered in wet areas especially on the river banks as small patches. It is common to occur as large communities in eastern Indonesia (Steenis, 1935a, 1935b; Johns et al., 2007; Whitmore, 1986).

The herbaceous vegetation, occurring in Java (Steenis et al., 1972) and Bali (Whitten et al., 1996) may consist of a diversity of grasses (e.g., *Phragmites karka*), sedges (especially the species of *Cladium*, *Cyperus*, *Eleocharis*, *Fimbristylis*, *Kyllinga*, *Rhynchospora* and *Scirpus*), and a variety of herbs, such as *Equisetum*, *Limnocharis*, *Monochoria*, *Oenanthe* and *Polygonum*.

Photo: Wawan Sujarwo (2019)

Figure 3.6 Lotus (*Nymphaea* spp.), An Example of Species in Freshwater Swamp Vegetation

Kern (1974) indicates that the following species of *Cyperaceae* constitute characteristic and common species in swamp vegetation throughout Indonesia: *Cladium mariscus*, *Cyperus babakan*, *Cyperus digitatus*, *Cyperus distans*, *Cyperus elatus*, *Cyperus exaltata*, *Cyperus halpan*, *Cyperus haloschoenus*, *Cyperus imbricatus*, *Cyperus iria*, *Cyperus malaccensis*, *Cyperus nutans*, *Cyperus odorus*, *Cype-*

rus pilosus, *Cyperus platystylis* (rare), *Cyperus palystachyos*, *Cyperus procerus*, *Cyperus pulcherrmus*, *Cyperus pygmaeus* (rare), *Cyperus sanguinolentus*, *Cyperus scariosus*, *Cyperus tenuispica*, *Elaeocharis retroflexa*, *Fimbrystylis acuminata*, *Fimbrystylis aestivalis*, *Fimbrystylis aphylla*, *Fimbrystylis complanata*, *Fimbrystylis ferruginea*, *Fimbrystylis globulosa*, *Fimbrystylis griffithii*, *Fimbrystylis intonsa* (rare), *Fimbrystylis littoralis*, *Fimbrystylis miliacea*, *Fimbrystylis perlaxa* (rare), *Fimbrystylis termicula* (rare), *Fimbrystylis terragona*, *Fimbrystylis thomsonii*, *Fuirena* spp., *Lipocharpha chinensis*, *Machaerina disticha*, *Machaerina rubiginosa*, *Rhynchospora triflora*, *Scirpus articulatus*, *Scirpus grossus*, *Scirpus juncoides*, *Scirpus lacustris*, *Scirpus lateriflorus*, and *Scleria rugosa*. In the Flora of Bali (Girmansyah et al., 2013) only *Cyperus pilosus*, *Fimbrystylis aphylla* and *Scirpus articulatus* have been collected from Bali.

It was reported seasonal swampy woody vegetation occurred near Sumber Klampok in northwest Bali (Soepadmo, 1961). The swampy sites dried out during the dry season. *Eugenia* sp., (*klampok*) grew abundantly around the sites.

G. Riparian Vegetation

The riparian vegetation ranges from communities of herbs, woody herbs and shrubs to tall forests growing along rivers with strong to slow running water (Figure 3.7). Various plant species with narrow leaves (stenophyl) and short stature belonging to different families but having similar physiognomy may form a unique community growing on rocks and firm river-bank soils or at the bottom of strong flowing rivers with their roots strongly penetrate rock crevices and solid substrates. The communty is very resistant to impact of strong flowing water. The seeds and fruits of the species composing the community are dispersed by water or fish.

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.7 Typical riparian vegetation in Bali as can be seen in Dauh Waru, Jembrana.

Steenis (1975) collectively designate these special groups of plants as rheophyte. Unique rheophytes include *Homonoia riparia*, *Garnotia stricta*, *Myrmeconauclea strigosa*, *Neonauclea rheophila*, *Enaulophyton lanceolatum*, species of Aglaia, *Eugenia*, *Antidesma*, *Carex*, *Ficus*, *Nauclea* and species of different families (e.g., *Euphorbiaceae*, *Melastomataceae*, *Meliaceae*, *Myrtaceae*, *Pandanaceae*, *Rubiaceae*, *Vitaceae*, and several other herbaceous families). *Cissus verticillata* is a member of Vitaceae that is frequently found in Balinese riparian vegetation as the dominant liana (Figure 3.8). In Bali, the climbing pandans of the genus, especially *Freycinetia scandens*, are often found very close to the rivers, and thus can also be regarded as a member of riparian vegetation (Figure 3.9).

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.8 *Cissus verticillata*, A Dominant Riparian Liana in Dauh Waru, Jembrana

A. Habit B. Infructescence

Photo: Ary **Prihardhyanto Keim (2014)**

Figure 3.9 The Climbing Pandan *Freycinetia scandens* Found Climbing on a Tree Very Close to a River in Dauh Waru, Jembrana

H. Herbaceous Beach Vegetation

Steenis (1958a) divided beach vegetation into herbaceous pes-caprae formation and Barringtonia forest formation. The pes-caprae formation or known also as pes-caprae community, described here, occur in all parts of Indonesia and in tropical Asia-Pacific regions (Kartawinata, 1965, 2013; Steenis & Schippers-Lammertse, 1965; Paijmans, 1975; Whitten et al., 1996; Monk et al., 1997; Mueller-Dombois & Fosberg, 1998). The pes-caprae community consists mostly of creeping herbs with stems above and below ground growing behind the beach line. It is dominated by *Ipomoea pes-caprae* and other creeping and deeply rooting herbs, tolerant to salt water and high temperature. It is a pioneer vegetation of the primary succession on the beach. Most of the species bear fruits and seeds floating in water or easily blown by wind. Fruits, seeds, and other propagules of a variety of herbs and woody plants are floating in sea water and landing along the beach as debris when sea water receded.

The dominant species are a creeping herb, Ipomoea pes-caprae, mixed with other creeping species (*Canavalia maritima* and *Vigna marina*), grasses (*Ischaemum muticum*, *Spinifex littoreus*, *Spinifex longifolius*, and *Thuarea involuta*) (Figure 3.10), succulent plant (Sesuvium portulacastrum) and other species, including *Euphorbia atoto*, *Ipomoea imperati*, *Ipomoea denticulata*, *Ipomoea littoralis*, *Lepturus repens*, *Remirea maritima*, *Wollastonia biflora*, *Stachytarpheta jamaicensis*, and *Triumfetta repens* (Steenis, 1935a, 1935b; Kartawinata, 1965; Steenis & Schippers-Lammertse, 1965). Frequently a parasitic plant *Cassytha filiformis* may be found strangling the host plants. Kern (1974) notes that the species of the family Cyperaceae characterizing sandy beaches are *Cyperus bulbosus*, *Cyperus dubius*, *Cyperus*

hyalinus, *Cyperus pedunculatus*, *Cyperus radians*, *Cyperus stoloniferus*, *Fimbristylis cymosa*, and *Fimbristylis sericea*. All species have rhizomes for vegetative propagation, which in some species, such as *Cyperus pedunculatus*, grow very long. Some rare species may be found here, such as *Cyperus bulbosus*, *Cyperus dubius*, and *Cyperus hyalinus*.

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.10 The herbaceous beach vegetation of the Pengambengan Beach, Jembrana is dominated by *Spinifex littoreus*.

I. Monsoon Coastal Forest

A coastal forest in a monsoon region occurs along a coast behind sandy beach covered by *pes-caprae* community or on a rocky coast, where sand deposits are absent on the beach continually washed away by waves. The forest is dominated by *Barringtonia asiatica* and is often called Barringtonia formation (Steenis, 1958b; Steenis & Schippers-Lammerste,

1965; Richards, 1996; Whitten et al., 1996). Rocky habitats usually occur along the hilly and rocky coastal areas, common in the Nusa Tenggara islands. In Bali, the coastal forests might have been disturbed and converted into resorts and other touristic areas, and the remnants of the undisturbed forest may be still present here and there as patches. *Barringtonia asiatica*, *Casuarina equisetifolia*, *Cerbera manghas*, *Pandanus tectorius*, and *Terminalia catappa* are still growing and maintained as ornamental trees in resorts and touristic areas (Figures 3.11).

The composition of undisturbed coastal forest is uniform throughout Indonesia, in areas with both wet and seasonal climates. Tree species composing a coastal forest include *Barringtonia asiatica*, *Calophyllum inophyllum*, *Casuarina equisetifolia*, *Cerbera manghas*, *Cocos nucifera*, *Colubrina asiatica*, *Erythrina variegata*, *Guettarda speciosa*, *Heritiera littoralis*, *Hernandia nymphaefolia*, *Hibiscus tiliaceus*, *Intsia bijuga*, *Morinda citrifolia*, *Pandanus tectorius*, *Pandanus dubius*, *Planchonela obovata*, *Pongamia pinnata*, *Terminalia catappa*, and *Thespesia populnea*. Two species jointly dominating the forest are *Barringtonia asiatica* and *Calophyllum inophyllum*, but *Barringtonia asiatica* is the most conspicuous and catching in appearance (Kartawinata, 1965; Steenis & Schippers-Lammerste, 1965; Whitten et al., 1996).

A dense population of *Pandanus tectorius* (Figure 3.12) usually characterizes the monsoon coastal forest behind sandy shores, in which they form dense thickets along the beach. *Pandanus dubius* is less common than *Pandanus tectorius* and prefers rather coral and rocky shores (Keim et al., 2020).

Usually communities of shrubs and small trees may be encountered between the forest and the *pes-caprae* communities. Species composing this community include *Ardisia el-*

liptica, *Caesalpinia bonduc*, *Clerodendrum inerme*, *Colubrina asiatica*, *Cycas rumphii*, *Desmodium umbellatum*, *Dodonaea viscosa*, *Erythrina variegata*, *Tournefortia argentea*, *Pemphis acidula*, *Pluchea indica*, *Premna corymbosa*, *Scaevola taccada*, *Sophora tomentosa*, and *Tacca leontopetaloides* (Figure 3.13; Figure 3.14).

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.11 Monsoon Coastal Forest in Delot Berawah, Jembrana with the Obvious Appearance of *Cocos nucifera* and *Barringtonia asiatica*

A. *Pandanus tectorius* in Jembrana

B. The Cephalia of *Pandanus tectorius*

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.12 A Dense Population of *Pandanus tectorius* that Dominates and Characterizes the Monsoon Coastal Forest behind the Sandy Shore in Delot Berawah, Jembrana

Photo: Kuswata Kartawinata (2004)

Figure 3.13 A degraded coastal forest dominated by *Pandanus tectorius* at Nusa Dua beach. In an undisturbed coastal forest, the leading species is a mixture of *Barringtonia asiatica*, *Calophyllum inophyllum*, and *Pandanus tectorius*.

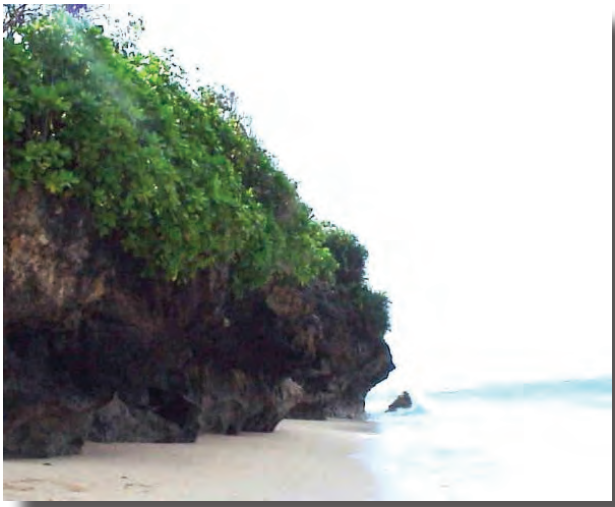


Photo: Kuswata Kartawinata (2004)

Figure 3.14 On a rocky coast, trees may be absent, but instead low shrubs, including *Scaevola taccada* may dominate the community, such as that found in the Nusa Dua beach.

In 2014 we observed that the monsoon coastal forest in Jembrana Regency, particularly along the Banjar Dangin Berawah Desa Perancak, and Desa Air Kuning (Yeh Kuning) has been invaded by an invasive species *Opuntia stricta*, a species of cactus (Cactaceae) (Figure 3.15). It is a native to the Americas and Caribbean (particularly USA, Mexico, and Cuba), which have been widely dispersed by humans and since has become serious invasive species in many places in Europe, Asia, and Australia (Anderson, 2001).

Actually, the cactus has even been declared as a serious invasive plant species by the Regency of Jembrana since 2007. Following that declaration the process of eradicating the cactus has been implemented and to date it is still continuing. However, the spread of the species proved to be very difficult to control, as observed in 2014 it was still abundant in the location. The species is also very difficult to be exterminated in Australia and it is apparently related with the vegetative apomixes (Pimienta-Barrios & Del Castillo, 2002).

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.15 *Opuntia stricta* (Cactaceae), an invasive species in Bali as can be seen massively invaded coastal area of Banjar Dangin Berawah, Desa Perancak, Jembrana.

J. Monsoon Lowland Evergreen Forest

Within the range of the monsoon region, forests may include seasonally deciduous forests and evergreen forests, where plants do not shed their leaves even during the severe drought period. The structure of the evergreen monsoon forest in general is similar to the evergreen rainforest, but shorter in stature and less complex in stratification. It is located in the Schmidt and Ferguson (1951) rainfall type E, which is strongly seasonal, where the natural vegetation can be monsoon evergreen lowland forest and monsoon seasonal deciduous lowland forest and savanna. It extends along the narrow strip of the north coast of Bali up to about Singaraja area as well as on the entire island of Nusa Penida (Figure 3.16).

The lowland forest at Mount Prapat Agung was described by Kartawinata (1958) and Soepadmo (1961). Mount Prapat Agung is located at a peninsula on the north-western tip of Bali and currently is the area of the Bali Barat National Park. The soil in the area was dominated by limestone rocks. Forests on the Mount Prapat Agung represented both the monsoon evergreen lowland forest and monsoon seasonal deciduous lowland forest. The forest was dominated by *Manilkara kauki*, whose natural distribution was restricted to the Prapat Agung area and did not extend to the neighboring Mount Sangiang range on the south. Habitat conditions appeared to be the factors separating the two areas. *Manilkara kauki* dominated the forest that extended from the beach up to the top of Mount Prapat Agung at the altitude of 700 masl and several deciduous species were present (Kartawinata, 1958).

Photo: Wawan Sujarwo (2018)

Figure 3.16 Monsoon Lowland Evergreen Forest Along the Coast of Nusa Penida

Trees were small in diameters and short in height, making the forest look more like a pole forest. In the past, *Manilkara kauki* was heavily exploited for its wood, which is one of the important and main sources of wood for making Balinese handicrafts, especially statues. Heavy timber exploitation, harvest of fruits by people, heavy predation of fruits by flying foxes and pigs, and grazing of seedlings by deer resulted in very poor regeneration. It was predicted that such situation would lead to the total disappearance of species from the area (Kartawinata, 1958) and the change of domination of the forest by other species or complete conversion to scrubs similar to those occurring on the neighboring lowland areas of northwest Bali (Kartawinata, 1958; Soepadmo, 1961). The forest at the top was still dominated by *Manilkara kauki*, mixed with *Albizia* sp., *Ficus callosa*, *Murraya paniculuta*,

Pterospermum acerifolium, *Planchonella ovata*, *Schoutenia ovata*, and *Vitex pubescens*. At the top, limestone rock outcrops were prominent, where such herbs as *Monophyllaea* sp., *Asplenium* sp., and *Adiantum caudatum* were growing.

A lowland forest at 400–600 masl can be found on the Mount Sangiang range at Negara in western Bali. The forest is located in the region moister than that on nearby Mount Prapat Agung in the northwest. The climate belongs to the rainfall type C of Schmidt and Ferguson (1951), which is slightly seasonal. The natural vegetation cover consisted of slightly seasonal lowland evergreen forest or the lowland monsoon evergreen forest. Kartawinata (1958) indicated that in this forest, *Planchonia valida* was the most prominent tree species, being the tallest trees with large buttresses and having characteristic red leaves prior to shedding. It belongs to the first stratum with the height of 20–30 m. Other species in this stratum included *Dysoxylum* sp., *Duabanga* sp., *Pterospermum javanicum*, *Alseodaphne* sp., *Hernandia guianensis*, *Palaquium javense*, *Duabanga moluccana*, *Meliosma ferruginosa* (Figure 3.17; Figure 3.18). Their distribution were scattered in contrast to species of the second stratum which were continuous with height of 15–20 m. They included *Aglaia* sp., *Alseodaphne* sp., *Beilschmiedia zeylanica*, *Bischofia* sp., *Buchanania javanica*, *Chrysophyllum* sp., *Dracontomelon dao*, *Dysoxylum* sp., *Dyospiros cauliflora*, *Elaeocarpus* sp., *Eugenia* sp., *Litsea* sp., *Mastixia* sp., *Myristica* sp., *Neonauclea* sp., *Phoebe* sp., *Pygeum* sp., and species of *Rubiaceae* and *Annonaceae*. The third stratum consisted of small trees and shrubs, such as species of *Ardisia* sp., *Aglaia* sp., *Ficus* sp., *Phyllanthus* sp., *Saurauia* sp., etc. *Laportea* sp. was present, indicating moist forest. The herbs constituting the undergrowth layer were species of *Acanthaceae*, *Araceae*, *Capparidaceae*, *Gesneriaceae*, *Maranthaceae*, *Orchidaceae*, *Piperaceae*, and *Rubiaceae* (Figure 3.19). The common epiphytes were *Spathoglotis* and *Fagraea*.

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.17 Monsoon Lowland Evergreen Forest in Dauh Waru, Jembrana at 400 to 500 m Altitude with the Presence of *Pterospermum javanicum* Characterized by Tall Tree with White Bark

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.18 *Duabanga moluccana* in Monsoon Lowland Evergreen Forest in Dauh Waru, Jembrana Showing the Tall Habit and Obvious Strong Buttress.

A. *Piper miniatum* B. *Piper caninum*

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.19 *Piper miniatum* and *Piper caninum* Found in Dauh Waru, Jembrana at About 400 m Altitude

Soepadmo (1961) reported that dipterocarp species, *Hopea sangal*, was present in this forest and further in the interior *Dipterocarpus* was rather common. *Fraxinus griffithii* was recorded to be present here at an attitude of 300 masl, which is interesting since according to Steenis (1935a, 1935b) this species occurs only above 1,000 m altitude.

It is interesting to note that about 10-hectare pure stand of *Dipterocarpus hasseltii* found in Sangeh, 15 km north of Denpasar, surrounded by rice fields, villages, hotels and rural roads, at ± 50 masl. Steenis (1935a, 1935b) stated that the dipterocarp trees were planted, but Tantra (1982) stressed otherwise that it was a remnant of a natural forest. The local community considered it a sacred forest. It should be noted that most of Dipterocarpaceae specifically grow

in lowland moist rain forests of Sumatra and Kalimantan. Sangeh, however, is located in the more moist site within the slightly seasonal lowland evergreen forest region with rainfall type C of Schmidt and Ferguson (1951) scheme, where Q = 33.3-60. Tantra (1982) noted that *Dipterocarpus hasseltii* was the dominant species and could reach a diameter at breast height of 198 cm. He undertook a total enumeration of flowering plants and recorded a total of 50 species and 37 families as follows: *Adenanthera pavonina*, *Agelaea macrophylla*, *Aglaia* sp., *Aglaonema simplex*, *Alstonia scholaris*, *Anamirta cocculus*, *Antidesma bunius*, *Ardisia humilis*, *Ardisia fuliginosa*, *Arenga pinnata*, *Baccaurea javanica*, *Buchanania arborescens*, *Calophyllum inophyllum*, *Chloranthus officinalis*, *Chrysophyllum roxburghii*, *Cissus nodosa*, *Clausena anisata*, *Clerodendrum speciosissimum*, *Corymborkis veratrifolia*, *Desmos chinensis*, *Dipterocarpus hasseltii*, *Eria* sp., *Ficus kurzii*, *Ficus magnolifolia*, *Flacourtia indica*, *Flacourtia rukam*, *Garcinia celebica*, *Garcinia* sp., *Justicia gendarusa*, *Glycosmis pentaphylla*, *Harpulia* sp., *Hiptage benghalensis*, *Ipomoea alba*, *Ixora paludosa*, *Leea aequata*, *Leea angulata*, *Leea indica*, *Litsea glutinosa*, *Litsea* sp., *Melothria* sp., *Merremia umbellata* subsp. *orientalis*, *Michelia champaca*, *Nephelium* sp., *Piper caninum*, *Pisonia umbellata*, *Psychotria corymbosa*, *Psychotria* sp., *Oxyceros patulus*, *Rubus rosifolius*, *Tetracera scandens*, *Syzygium cumini*, *Tetrastigma lanceolarium*, *Trevesia sundaica*, *Tylophora* sp., and *Ziziphus horsfieldii* (Figure 3.20).

The genus *Tabernaemontana* is also found in the monsoon lowland evergreen forests of Bali mainly represented by *Tabernaemontana macrocarpa* and *Tabernaemontana sphaerocarpa* as was observed in Dauh Waru, Jembrana at about 400 m altitude in 2014. Apparently, this information is the first record of the two species growing as cohabinant. The presence of these two species in Bali is acceptable as the

two species are natives and found wide spread throughout the Malesian region (Middleton, 2007). *Tabernaemontana sphaerocarpa* is less wide spread than *Tabernaemontana macrocarpa* (Figure 3.21). Nevertheless, *Tabernaemontana sphaerocarpa* is found from Java to the Moluccas (Middleton, 2007); thus, the distribution areas of the two species are indeed overlapping.

Dysoxylum arborescense was also found fairly abundant in the monsoon lowland evergreen forest in Lalang Hill of Dauh Waru, Jembrana around 400 to 450 m altitudes. *Dysoxylum arborescence* is a wide spread species and widely dispersed throughout the Malesian region, including Bali (Mabberley, 2007) (Figure 3.22). The other more commonly seen species, *Dysoxylum densiflorum* or known as *Majegau* by Balinese, was also found and both species were cohabitants. The members of *Icacinaceae* were represented by *Platea excelsa*, which was observed fairly abundant throughout the same vicinities. The climbers from the family *Menispermaceae* were also found fairly abundant in Dauh Waru, particularly *Tinospora cordifolia*. This species is well known by the Balinese and also by the Javanese and Sundanese of the neighboring island of Java as *bratawali* or *antawali* and used traditionally as medicine for rheumatism, diabetic, and fever (Figure 3.23).

A. *Antidesma bunius* B. *Platea excelsa*

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.20 *Antidesma bunius* and *Platea excelsa* in Dauh Waru, Jembrana at About 400 m Altitude.

A. *Tabernaemontana sphaerocarpa* B. *Tabernaemontana macrocarpa*

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.21 *Tabernaemontana sphaerocarpa* and *Tabernaemontana macrocarpa* grow as cohabitants in the monsoon lowland evergreen forest in Dauh Waru, Jembrana at about 400 m altitude.

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.22 *Dysoxylum arborescens* in the Monsoon Lowland Evergreen Forest in Dauh Waru, Jembrana at About 400 m Altitude

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.23 The legendary *bratawali* or *antawali* (*Tinospora cordifolia*; *Menispermaceae*) found in Dauh Waru, Jembrana at about 400 m altitude shows the fruits and climbing stem with distinctive nodules collected by local people for medicinal purposes.

The palm flora of Bali is also amazing in this vegetation type. At least there were eight species observed in Dauh Waru, Jembrana at elevation about 400 to 500 masl in 2014, i.e. *Areca catechu*, *Arenga pinnata*, *Calamus javensis*, *Calamus melanochaetes*, *Calamus rubra*, *Caryota mitis*, *Cocos nucifera*, *Pinanga coronata*, and *Pinanga javana*.

As anywhere in Indonesia and also areas within the realm of the Austronesian civilization, *Areca catechu* has never been found in the wild. This species is always planted as a cultivated plant and regarded very important by the Balinese and the rest of the Austronesians, at least from Sumatera to Sulawesi (i.e. West Central Austronesia).

The same is also for the legendary *nyiur* or *kelapa* or scientifically known as *Cocos nucifera*. Every parts of *Cocos nucifera* are useful for the Balinese (and of course for the majority of the Austronesians as well, particularly the cousins of the Balinese that are the Javanese and Sundanese), including the leaves, which are constantly harvested for making baskets for offerings in their daily pray. It is not surprising to find that *Cocos nucifera* is massively planted in Bali. Despite it is also massively planted as cultivated plants by the Balinese, particularly for the rich sugar sap harvested (tapped) from the inflorescence as the source for palm sugar and the traditional alcoholic beverage called *tuak*, it can still scarcely be found as wild or semi wild plants (Figure 3.24).

Caryota mitis was more commonly found in monsoon lowland evergreen forests of Bali as can be seen in Lalang hill in the vicinity of Dauh Waru, Jembrana especially between 400 to fairly 500 m altitudes. Although *Caryota mitis* was also widely planted as ornamental plants, this species still can be found abundantly in the forests, particularly lowland tropical rainforest up to around 500 m altitudes (Uhl & Dransfield, 1987; Dransfield et al., 2008; Quattrocchi, 2017). Like its *Caryoteae* cousin, *Arenga pinnata*, almost all parts of *Caryota mitis* are applied by Balinese for their religious

offerings, especially the black fibres produced by the disintegrated margins of leaf sheats (Sujarwo et al., 2020) (Figure 3.25; Figure 3.26).

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.24 Coconuts (*Cocos nucifera*) are massively planted in Dauh Waru, Jembrana at about 300–350 m altitude side by side with introduced and enormously planted clove trees, *Syzygiun aromaticum*.

(A) *Arenga pinnata* in the wild of Dauh Waru, Jembrana at about 400 m altitude; (B) People harvest the sugar rich sap from the inflorescence in Tasikmalaya and other regions in West Java.

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.25 The practice done by the Balinese and the rest of the people in West-Central Austronesia.

(A) *Caryota mitis* in the vicinity of Dauh Waru at about 400 m altitude showing juvenile with the distinctive double pinnate leaves; (B) Mature individual with the characteristic hapaxanthic infructescences

(C) Leaf Sheath; (D) Infructescence

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.26 *Caryota mitis*

There are three species of the tree palm genus of *Pinanga*: *Pinanga arinasae*, *Pinanga coronata*, and *Pinanga javana*, in which *Pinanga arinasae* is endemic to Bali (Witono et al., 2002; Witono, 2003) (Figure 3.27). *Pinanga coronata*

and *Pinanga javana* were wide spread throughout the Balinese monsoon lowland evergreen forests, whereas *Pinanga arinasae* was so far restricted to the hilly forests around Bedugul, in the northern-central section of Bali.

A. *Pinanga coronata*

B. *Pinanga javana*

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.27 *Pinanga* spp. from Dauh Waru, Jembrana at 400 to 500 m Altitudes

The rattan flora is in general similar with the rattan flora of Java. The wide spread species commonly found in Java, such as *Calamus javensis* and *Calamus melanochaetes* were also found in Bali from coastal area up to approximately 1,000 m altitudes (Figure 3.28). *Calamus melanochaetes* is a species that inhabits various kind of habitats, from coastal and mangrove areas up to lowland tropical rainforests.

There is another species of robust rattan found in the monsoon lowland evergreen forest of Dauh Waru, Jembrana, which was in this book identified as *Calamus rubra*, previously known as an endemic species to Java Island (Figure 3.29). The presence of this species in Bali is not surprising due to Sundaland connection, in which Bali was once connected with Java, Sumatera, Borneo, and the Malay Peninsula to form a subcontinent, Sundaland. Just like the presence of *Calamus melanochaetes* in Bali (Figure 3.30), which was just recently reported in Bali (Rustiami, 2016).

We recorded a fascinating discovery in Lalang Hill, where small birds make nest in the obvious spiny cirrus of *Calamus melanochaetes* (Figure 3.31). Apparently the birds make the cirrus as the nesting area for the safety purposes, protected by the sharp spines. This discovery is just adding the life complexity in the already complex monsoon lowland evergreen forest of Bali.

(A) *Calamus javensis*; (B) Leaf sheath covered with white indumentum and spines with an obvious knee and characteristic pairs of leaflets on the basal of rachis; (C) An axillary long infructescence with rounded light creamy yellow scaly fruits; (D) Rattan canes

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.28 *Calamus javensis* Found in Dauh Waru, Jembrana at about 500 m Altitudes

(A) *Calamus rubra*; (B) Stem with conspicuously dense reddish brown spines and axillary infructescences; (C) Leaf sheath with densely crowded arranged spines; (D) A long infructescence
Photo: Ary Prihardhyanto Keim (2014)

Figure 3.29 *Calamus rubra* Found in Lalang Hill, Dauh Waru, Jembrana at About 500 m Altitude

(A) *Calamus melanochaetes* with conspicuous spiny leaf sheaths, knees, and axillary infructescenses; (B) The obvious dark black spines; (C) The scaly fruits covered with spiny peduncular bracts; (D) Rattan canes

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.30 *Calamus melanochaetes* Found in Lalang Hill, Dauh Waru, Jembrana at About 500 m Altitude

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.31 A Bird Nest in the Cirrus of *Calamus melanochaetes* Found in Lalang Hill, Dauh Waru, Jembrana

Unlike its palm flora, the pandan flora of Bali is still largely shrouded in mystery. At least there has been reported few species, mainly of the genus *Pandanus* such as *Pandanus dubius*, *Pandanus faviger*, *Pandanus tectorius*, and a taxon found in Lalang Hill, Dauh Waru, Jembrana which is at the moment still identified as *Pandanus furcatus* (Keim et al., 2020) (Figure 3.32).

There has been very few information regarding the genus *Freycinetia* of Bali. In the field so far only *Freycinetia insignis* and *Freycinetia scandens* have ever been reported (Keim et al., 2020) (Figure 3.33; Figure 3.34). No information regarding the genus *Benstonea* has ever been reported although there is a strong possibility of the presence of *Benstonea kurzii* in Bali.

(A) *Pandanus furcatus* showing clustered habit; (B) Prop roots; (C) A Terminal hanging cephalium still enclosed by peduncular bracts; (D) Cephalium with forked stigmas

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.32 *Pandanus furcatus* from Lalang Hill, Dauh Waru, Jembrana at Around 300 to 325 m Altitude

(A) *Freycinetia scandens*; (B) Terminal infructescence with 3 cephalia; (C) Three lanceolate-elongate ellipsoidal cephalia per infructescence with berries each with one stigma; (D) Mature infructescence with crimson red cephalia mature infructescence with crimson red cephalia

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.33 *Freycinetia scandens* from Dauh Waru, Jembrana at 250 m Altitude

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.34 Infructescences of *Freycinetia scandens* Collected in Dauh Waru, Jembrana with 3 and 4 Cephalia

The outstanding richness of plant species in the monsoon lowland evergreen forest undoubtedly makes this vegetation type as the biologically most diverse vegetation type in Bali as well as in the entire Malesian region.

K. Lowland Deciduous Monsoon Forest

Deciduous monsoon forest and evergreen monsoon forest may be distinguished on the basis of the percentage of the deciduous species. A forest may be designated as deciduous forest if the percentage of deciduous species >50%, (Steenis, 1957; Steenis & Schippers-Lammertse, 1965), but in the field it is not easy to do so. The presence of the characteristic species, however, may be useful in identifying a deciduous forest. The following species are the characteristic species of the lowland deciduous forest, in its range of distribution from East Java to East Nusa Tenggara, included Bali

(Steenis, 1957; Steenis & Schippers-Lammerste, 1965; Whitmore, 1986), i.e., *Acacia leucophloea*, *Acacia tomentosa*, *Aegle marmelos*, *Ailanthus integrifola* subsp. *calycina*, *Albizia chinensis*, *Albizia lebbekoides*, *Azadirahta indica*, *Bauhinia malabarica*, *Borassus flabellifer*, *Butea monosperma*, *Caesalpinia digyna*, *Cassia fistula*, *Cordia dichotoma*, *Corypha utan*, *Dalbergia latifolia*, *Dillenia pentagyna*, *Exocarpus latifolia* (rare), *Feronia limonia*, *Garuga floribunda*, *Garuga pinnata*, *Homalium tomentosum*, *Lannea coromandelica*, *Melia azedarach*, *Peltophorum pterocarpum*, *Phyllanthus emblica*, *Protium javanicum*, *Pseudobombax septenatum*, *Pterospermum diversifolium*, *Salmalia malabarica*, *Santalum album* (rare), *Schleichera oleosa*, *Schoutenia ovata*, *Stereospermum suaveolens*, *Streblus asper*, *Tamarindus indica*, *Tectona grandis*, *Terminalia bellirica*, *Tetrameles nudiflora*, *Ziziphus jujuba*, and *Ziziphus nummularia*. Among shrubs the following species are included, i.e., *Atalantia trimera*, *Capparis* spp., *Cassine glauca*, *Cladogynos orientalis*, *Clausena harhmandiana*, *Dichrostachys cinerea*, *Diplophractum auriculatum*, *Glinus lotoides*, *Harrisonia* spp., *Putranjiva roxburghii*, and *Woodfordia fruticose*. Among herbs include *Athroisma laciniatum*, *Barleria* spp., *Blepharis* spp., *Curcuma* spp., *Goodenia kooningsbergeri*, *Helicteres angustifolia*, *Pentapetes* sp., *Phoenicia* sp., as well as many species of the families *Cyperaceae*, *Convolvulaceae*, *Gramineae*, *Leguminosae*, *Malvaceae*, and *Rhamnaceae* which are restricted to the monsoon forest. It should be noted that from the above list of species they are not necessarily always found throughout the monsoon area; each species has its own preferences.

Structurally the forest possessed only one layer of tree crowns with height of < 25 m and emergent trees were usually rare. Trees were low-branched and the boles were seldom straight. Species composition was poor and each species tended to form local dominant. Bamboos were gen-

erally common but tree ferns and conifers were very rare. Annuals, tuberous plants and climbers are abundant. Many tree species were deciduous, such as *Acacia leucophloea*, *Erythrina variegata*, *Melaleuca leucadendra*, *Pterospermum diversifolium*, *Schoutenia ovata*, *Schleichera oleosa*, *Sterculia foetida*, etc.

Kern (1974) indicated that in the monsoon region with pronounced dry season several sedge species grew on swampy areas flooded during the rainy season, but usually easily burned during the dry season. They were *Carex stramentitia*, *Carex tricephala*, *Cyperus alopecuroides*, *Cyperus angustatus*, *Cyperus bulbosus*, *Cyperus holoschoenus*, *Cyperus nervulosus*, *Cyperus paniceus*, *Cyperus squarrosus*, *Fimbristylis adenolepis*, *Fimbristylis anisoclada*, *Fimbristylis bisumbellata*, *Fimbristylis blepharolepis*, *Fimbristylis dictyocolea*, *Fimbristylis fimbristyloides*, *Fimbristylis furvainsignis*, *Fimbristylis lanceolata*, *Fimbristylis macassarensis*, *Fimbristylis microcarya*, *Fimbristylis recta*, *Fimbristylis schultzii*, *Fimbristylis semarangensis*, *Fimbristylis sieberiana*, *Fimbristylis subalata*, *Fimbristylis subdura*, *Fimbristylis sumbaensis*, *Fimbristylis wetarensis*, *Gahnia aspera*, *Lipocarpha microcephala*, *Rhynchospora hookeri*, *Schoenus sparteus*, *Scleria junghuniana*, and *Scleria psilorrhiza*.

Kartawinata (1958) and Soepadmo (1961) noted in the monsoon scrub near Gilimanuk, which was apparently degraded monsoon forest (Figure 3.35), the common shrubs and trees included *Albizia lebbekoides*, *Anisophylea* sp., *Buchanania* sp., *Calotropis gigantea*, *Capparis sepiana* var. *fischeri*, *Cathormion umbellatum*, *Ficus callosa*, *Garuga floribunda*, *Glycosmis* sp., *Kleinhovia hospita*, *Mallotus* sp., *Pterocymbium javanicum*, *Schoutenia ovata*, *Streblus asper*, *Strychnos* sp., *Uvaria* sp., *Vitex pinnata*, and *Zanthoxylum rhetsa*. A few old *Manilkara kauki* trees together with *Cordia flavescens* and *Excoecaria agallocha* were also present. Many shrubs were thorny and their leaves covered

by wax layers, typical seasonal vegetation characteristics. *Cyathocalyx sumatranus*, *Eupatorium inulifolium*, *Lantana camara*, *Shoutenia ovata*, *Streblus asper*, *Vernonia cinerea*, and *Xanthophyllum excelsum* were reported to be grazed by deer (Masy'ud et al., 2008).

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.35 *Calotropis gigantea* Found in the Open Area of Pengambengan Beach, Jembrana

Roemantyo (2011) did a more intensive botanical survey at Labuan Lalang within the Bali Barat National Park and came up with a more species of different life forms (Figure 3.36). In the tree life form he recorded *Acacia leucophloea*, *Acacia nilotica*, *Acacia* sp., *Albizia* sp., *Albizia lebekkoides*, *Alstonia angustifolia*, *Azadirachta indica*, *Berrya cordifolia*, *Bridelia monoica*, *Celtis philippensis*, *Cordia dichotoma*, *Cordia myxa*, *Cordia* sp., *Crateva adansonii* subsp. *odora*, *Croton* sp., *Croton argytatus*, *Dalbergia latifolia*, *Dichrostachys cineria*, *Dodonaea viscosa*, *Excoecaria agallocha*, *Ficus*

sp., *Ficus microcarpa*, *Ficus virens*, *Ficus superba*, *Flacourtia indica*, *Guazuma ulmifolia*, *Guioa* sp., *Grewia eriocarpa*, *Heritiera littoralis*, *Hibiscus tiliaceus*, *Leea* sp., *Lepisanthes rubiginosum*, *Litsea* sp., *Melaleuca leucadendra*, *Micromelum minutum*, *Mimusops elengi*, *Morinda citrifolia*, *Osbornia octodonta*, *Phyllanthus emblica* (Figure 3.37), *Pongamia* sp., *Protium javanicum*, *Radermachera* sp., *Santalum* sp., *Schleichera oleosa*, *Schoutenia ovata*, *Sterculia foetida*, *Streblus asper*, *Strychnos lucida*, *Syzygium* sp., *Tamarindus indica*, *Tectona grandis*, *Thespesia populnea*, *Trema orientalis*, *Vitex pubescens*, *Vitex trifolia*, and *Zanthoxylum rhetsa*. In the shrub life form the following species were recorded: *Abutilon indicum*, *Aegiceras floridum*, *Ardisia humilis*, *Bauhinia* sp., *Barleria* sp., *Boehmeria* sp., *Breynia virgata*, *Brucea javanica*, *Callotropis gigantea*, *Canthium horridum*, *Cascabela thevetia*, *Cassia* sp., *Chromolaena odorata*, *Clausena* sp., *Clerodendrum inerme*, *Dendromyza* sp., *Ehretia microphylla*, *Erythrina variegata*, *Feroniella* sp., *Flacourtia* sp., *Glochidion* sp., *Glycosmis* sp., *Helicteres isora*, *Jatropa* sp., *Josephinia imperatricis*, *Lantana camara*, *Mimosa pudica*, *Musaenda* sp., *Ormocarpum sennoides*, *Pemphis acidula*, *Rauvolfia serpentina*, *Senna surattensis*, *Senna alata*, *Sesbania cannabina*, *Thespesia lampas*, *Todalia* sp., *Trema cannabina*, and *Ziziphus nummularia*. The forest seems to have a closed canopy as there were only a few herbs which mostly are species characterizing open sites noted as follows: *Ageratum conyzoides*, *Abrus precatorius*, *Blumea lacera*, *Cynodon dactyton*, *Desmodium* sp., *Eleusine indica*, *Euphorbia hirta*, *Hydrocotyle* sp., *Ocimum basillicum*, *Ottochloa nodosa*, *Phyllanthus niruri*, *Poganatherum paniceum*, *Sida rhombifolia*, *Spilanthes* sp., *Vernonia cinerea*, and *Wollastonia biflora*. The other life form comprises the following creepers and climbers: *Bauhinia fulfa*, *Calopogonium mucunoides*, *Cissus repens*, *Deeringia* sp., *Fibraurea* sp., *Luffa aegyptiaca*, *Merremia tridentata*, *Olax imbricata*, *Passiflora foetida*, *Porana volubilis*, *Uvaria rufa*, and *Ziziphus horsfieldii*.

Photo: Roemantyo (2011)

Figure 3.36 Deciduous Lowland Monsoon Forest with a Cluster of Evergreen Trees and Shrubs in the Matrix of Deciduous Low Stature Trees and Shrubs at Bali Barat National Park

Photo: Roemantyo (2011)

Figure 3.37 An evergreen tree of *kemlaka* (*Phyllanthus emblica*) that never shed its leaves during the even severe drought seasons in the deciduous lowland monsoon forest at the Bali Barat National Park. The forest and the tree are the habitat of the endangered Balinese white sterling (*Leucopsar rothschildi* Stresemann, 1912) as indicated by an arrow, which is also endemic to West Bali.

In the remnants of dry forest of Bukit Jimbaran, Bali (Figure 3.38), Sujarwo and Arinasa (2013) recorded the following tree, shrub, and herb species *Abutilon indicum*, *Acacia auriculiformis*, *Adiantum philippense*, *Alstonia scholaris*, *Amorphophalus campanulatus*, *Amorphophalus paeoniifolius*, *Andrographis paniculata*, *Anisomeles indica*, *Azadirachta indica*, *Blighia sapida*, *Bridelia monoica*, *Caesalpinia bonduc*, *Callotropis gigantea*, *Canavalia* sp., *Capparis micracantha*, *Capparis* sp., *Cassia fistula*, *Cayratia trifolia*, *Cipadessa baccifera*, *Clerodendrum* sp., *Cordia subcordata*, *Cyperus rotundus*, *Desmodium heterophyllum*, *Dichroa febrifuga*, *Diospyros macrophylla*, *Eleusine indica*, *Chromolaena odorata*, *Euphorbia tirucalli*, *Ficus septica*, *Flacourtia indica*, *Geodorum densiflorum*, *Gliricidia sepium*, *Gloriosa superba*, *Indigofera tinctoria*, *Ipomoea maxima*, *Jasminum mutiflorum*, *Jatropha gossypifolia*, *Lannea coromandelica*, *Mimosa pudica*, *Momordica charantia*, *Morinda citrifolia*, *Muntingia calabura*, *Oplismenus burmanni*, *Bauhinia fulfa*, *Phyllanthus niruri*, *Premna corymbosa*, *Rauvolfia serpentina*, *Ricinus communis*, *Santalum album*, *Sapium sebiferum*, *Schleichera oleosa*, *Senna surattensis*, *Sterculia foetida*, *Streblus asper*, *Syzygium aqueum*, *Tacca palmata*, *Tephrosia candida*, *Tetrastigma laevigatum*, *Uvaria rufa*, *Zingiber montanum*, and *Ziziphus nummularia*.

L. Monsoon Savanna

This type of vegetation may consist of grasslands or scrubs dotted with sparse and scattered trees; whose crowns are not touching. Monsoon savanna occurred in East Java, West Bali, West Nusa Tenggara, East Nusa Tenggara, Southeast Sulawesi, and Southeast Papua (Steenis, 1935a, 1935b; Meijer Drees, 1951; Steenis & Schippers-Lammerste, 1965; Whitmore, 1986; Whitten et al., 1987; Monk et al., 1997; Walujo, 2000; Marshall & Beehler, 2007). Common and dominant grass species constituting the matrix of monsoon savanna

is Heteropogon contortus. The tree species component includes *Acacia leucophloea*, *Albizia chinensis*, *Borassus flabellifer*, *Casuarina junghuhniana*, *Corypha utan*, *Eucalyptus* spp., *Melaleuca leucadendra*, *Schleichera oleosa* and *Tectona grandis*.

Photo: Wawan Sujarwo (2012)

Figure 3.38 Tropical dry forest of Bukit Jimbaran near Udayana University campus at the background and the early successional herbaceous community on disturbed habitat at the foreground. *Calotropis gigantea* on the left is a typical medium-size shrub invading open ground in the seasonally dry area in Bali.

Kern (1974) recorded that the following species of *Cyperaceae* grow uniquely in savanna, i.e., *Fimbristylis cinnamometorum*, *Fimbristylis eragrostis*, *Fimbristylis falcata*, *Fimbristylis furva*, *Fimbristylis fusca*, *Fimbristylis insignis*, *Fimbristylis lanceolata*, *Fimbristylis ovata*, *Fimbristylis recta*, *Fimbristylis signata*, *Fimbristylis wetarensis*, *Rhynchospora heterochaeta*, *Rhynchospora longisetis*, *Rhynchospora ru-*

bra, *Rhynchospora subtenuifolia*, *Rhynchospora wightiana*, *Schoenus falcatus*, and *Schoenus punctatus*. Such savanna occurred in the western part of Bali between Gilimanuk and Singaraja and between Gilimanuk and Negara (Soepadmo, 1961). The tree species growing in the *Imperata* grassland matrix include *Borassus flabellifer*, *Corypha utan*, *Acacia leucophloea*, and *Phyllanthus emblica*. The shrub species encountered here were *Callotropis gigantea* and *Lantana camara*. The presence of charcoal at the base of the tree trunks indicated that the savanna here suffered regular burning during the dry season. Trees scattered here included *Buchanania arborescens*, *Heritiera littoralis*, *Pterospermum javanicum*, *Schoutenia ovata*, and *Kleinhovia hospita*. Eleven species in this savanna proved to be palatable to deers, i.e., *Acacia leucophloea*, *Alstonia scholaris*, *Azadirachta indica*, *Cyathocalyx sumatranus*, *Digitaria ciliaris*, *Eupatorium inulifolium*, *Imperata cylindrica*, *Lantana camara*, *Spilanthes iabadicensis*, and *Ziziphus mauritiana* (Masy'ud et al., 2008), of which *Digitaria ciliaris*, *Eupatorium inulifolium*, *Imperata cylindrica*, *Lantana camara*, and *Vernonia arborea* were common agricultural weeds successfully invaded the savanna community.

M. Monsoon Montane Forest

To date no published report for Bali on the description of monsoon montane forest, which is known also as seasonal montane forest. It is likely similar to those occurring in East Java (Steenis, 1972) and Nusa Tenggara (Meijer Drees, 1951; Monk et al., 1997) at the altitudes of 1,000–1,200 masl. In East Nusa Tenggara, the species of everwet montane forest, such as *Dacrycarpus imbricatus*, *Palaquium* sp., and *Planchonella* sp. are mixed with fire resistant tree species, *Casuarina jughuhniana* and *Angophora euryphylla*. The latter is an endemic species to East Nusa Tenggara, which in many areas constitutes a dominant species (Monk et al., 1997; Walujo,

2000). Other common species include *Eucalyptus alba* and *Maclura amboinensis*. However, *Angophora euryphylla* and *Eucalyptus alba* do not occur in Bali.

It is likely that seasonal montane forest in Bali could be ecologically and compositionally comparable, if not similar, to that in East Java, considering the very close geographic position and climatic conditions. In East Java from Mt. Lawu to the east, all high mountains with elevation above 1,400 masl are covered by *Casuarina junghuhniana* forest (Steenis & Schippers-Lammerste, 1965; Steenis et al., 1972). The forest on this mountain range is the peak of successional changes, starting with burned communities followed by the regrowth of species through growth of seedlings and re-sprouts. In this region, forests often appear in several stages of development from a few trees scattered in the grassland to savanna and eventually to closed forest.

N. Evergreen Montane Forest

In the mountain areas at the elevation ≥ 1,000 masl, several vegetation types can be identified, i.e., lower montane forest, upper montane forest, subalpine forest, subalpine scrub, and also herbaceous vegetation types (Steenis & Schippers-Lammerste, 1965; Steenis et al., 1972). The lower and upper montane forest types form a continuum, hence the changes are often gradual and the boundary is not easily distinguishable. Boundaries between vegetation types are clearly distinguishable at the altitudes higher than 2,400 masl (Kartawinata, 2005, 2013). As the altitude increases, generally trees become shorter and their diameters smaller. In this forest type the common tree species are those of *Fagaceae* and *Lauraceae*. Other tree species include *Dacrycarpus imbricatus*, *Engelhardia spicata*, *Eugenia banksii*, *Lithocarpus* spp., *Palaquium* spp., *Quercus* spp., *Schima wallichii*, *Turpinia pomifera*, and also tree ferns (*Cyathea*

spp.). Epiphytes and climbers are generally abundant. Mossy forests that harbor abundant mosses commonly developed at altitudes of 1,500-1,900 masl.

In Bali we have no published records of subalpine forest, subalpine scrub, and herbaceous vegetation types. The montane evergreen forest in Bedugul within the Batukaru nature reserve adjacent to the Bali Botanic Garden (Figure 3.39) was described by Kartawinata (1958) and Soepadmo (1961). The site is located at 1,500 masl, which was almost every afternoon covered by fog and the rain could fall continuously for a week or so. In Schmidt and Ferguson (1951) scheme, the rainfall in the area belongs to the type B with the Q = 13.3-33.3 indicating humid condition, where everwet and evergreen rain forest developed.

Photo: Wawan Sujarwo (2013)

Figure 3.39 The Montane Evergreen Forest within the Batukaru Nature Reserve on Gardens on the Background, along with Mixed Tree Gardens, Crop and Rice Field on the Foreground

Kartawinata (1958) and Soepadmo (1961) reported that by 1958 tree harvesting in the forest in the Bedugul area up to the mountain top had been going on since the Japanese occupation time. The species extracted included *Dacrycarpus imbricatus*, *Eugenia* sp., *Elaeocarpus* sp., and *Gordonea excelsa*, which actually constituted the main components of the forest. *Dacrycarpus imbricatus* was the dominant tree species that could reach approximately 30 m tall and 1 m diameter. It grew gregariously on slopes. The second tallest tree was *Casuarina junghuhniana*, growing in the ravines, but at the same time it was the dominant and the only species in the first stratum on ridges at the mountain top where soil was thin. On the slopes the soil was thick and friable, covered by forest with the first stratum consisted of *Castanopsis* sp., *Casuarina montana*, *Ficus* spp., *Engelhardia spicata*, *Elaeocarpus stipularis*, *Eugenia* spp., *Gordonia excelsa*, *Meliosma* sp., *Mischocarpus sundaicus*, *Neonauclea* sp., *Quercus* sp., and *Terminalia* sp., *Gordonia excelsa* could reach the height of 30 m and diameter of 80 cm and grew unreservedly. As mentioned above it was the species that became the target of logging, which left large gaps on the canopy because of its gregarious growth habit. The gaps were immediately invaded by fast growing species, including *Macaranga* spp., *Mallotus* sp., and *Homalanthus populneus*.

In the second stratum *Astronia* sp. was the most abundant, followed by *Persea rimosa* and species of *Acronychia*, *Aglaia*, *Adinandra*, *Elaeocarpus*, *Elatostachys*, *Glochidion*, *Lindera*, *Litsea*, *Macaranga*, *Neonauclea*, *Platea*, *Plyosma*, *Photinia*, *Weinmannia*, *Villebrunea*, *Rapanea*, *Wendlandia*, *Vernonia*, and *Viburnum*. No species of *Burseraceae*, *Myristicaceae*, *Annonaceae*, and *Dipterocarpaceae* were present; meanwhile Palms (including the climbing palms, rattan) were present. Trees with buttresses were rare. Climbers were dominated by *Piper* spp., which were present in almost every tree. Other less prominent climbers were *Aeschynanthus*, species of *Freycinetia* (particularly *Freycinetia insignis*

and *Freycinetia scandens*, the most wide spread species of the genus), *Hoya*, *Rhamnus*, *Rubus*, *Smilax*, and species of *Vitaceae*, *Urticaceae*, *Loranthaceae*, and *Arecaceae*. Epiphytes were mainly ferns, orchids and *Gesneriaceae*. They were abundant all the way up to the mountain top.

The most prominent ferns here were *Asplenium nidus*, and *Cyathea contaminans* (Figure 3.40). The common ground herbs included *Begonia sempervirens*, *Desmodium* sp., *Elatostema* sp., and species of *Acanthaceae*, *Boraginaceae*, *Campanulaceae*, *Cruciferae*, *Gesneriaceae*, *Labiatae*, and *Umbelliferae*. *Rubus moluccanus* and *Rubus rosifolius* were present and grew in clumps that formed thick and horizontal undergrowth. *Laportea* spp. were widespread and one of them was tree that could grow to about 20 cm in diameter and 30 m in height. Common shrubs were *Rhododendron javanicum*, species of *Ardisia*, *Breynia*, *Glochidion*, *Medinilla*, *Moghania*, *Saurauia*, and *Rubiaceae*.

(A) Cyathea contaminans showing the young habit (not yet showing the characteristic of a tree fern); (B) A coiled young leaf (circinate) showing the obvious reddish brown scales and dark spines

Photo: Ary Prihardhyanto Keim (2014)

Figure 3.40 *Cyathea contaminans* in Dauh Waru, Jembrana at 400 to 500 m Altitude.

A floristic composition record from one hectare plot of lower montane forest at Mt. Pohen in the Batukaru Nature Reserve, at the altitude of 1,600–1,700 masl listed 24 species of 19 families (Sutomo et al., 2012). It is poorer than that in montane forest of Mount Gede-Pangrango and Mount Halimun in West Java (Kartawinata, 2005) and slightly different from those reported by Kartawinata (1958) and Soepadmo (1961). Five most abundant species were *Acronychia trifoliata*, *Crypteronia paniculata*, *Claoxylon* sp., *Dacrycarpus imbricatus*, *Homalanthus giganteus*, *Lophopetalum javanicum*, *Rapanea hasseltii*, *Polyosma integrifolia* and *Vernonia arborea*. Other tree species composing the forest were *Ardisia* sp., *Breynia microphylla*, *Casuarina junghuhniana*, *Celtis* sp., *Engelhardia spicata*, *Ficus* sp., *Glochidion rubrum*, *Gordonia amboinensis*, *Litsea* sp., *Mischocarpus* sp., *Platea* sp., *Sloanea siguns*, *Symplocos* sp., and *Weinmannia blumei*. *Casuarina junghuhniana* was dominant in Batukaru Nature Reserve at altitudes of 1500-1900 masl. *Casuarina* dominance is a common feature in montane forests in Central Java and East Java, and often formed pure stands. Such pure stands developed after fire (Steenis et al., 1972).

Kartawinata (1958) and Soepadmo (1961) observed that forests along the Beratan and Batur Lakes were slightly disturbed (Figure 3.41, Figure 3.42), and recorded that the common species were secondary species, including species of *Evodia*, *Ficus*, *Macaranga*, *Mallotus*, *Saurauia*, and *Trema*. The species of primary forest that remained were those of the second stratum, including *Acronychia trifoliata*, *Astronia spectabilis*, *Dendrocnide stimulans*, *Dysoxylum acutangulum*, *Eugenia* spp., *Glochidion rubrum*, *Litsea resinosa*, *Persea rimosa*, *Platea latifolia*, *Polyosma integrifolia*, *Pygeum parvifolium* (rare). *Rapanea hasseltii*, *Weinmannia blumei*, *Viburnum* sp. (rare), *Wendlandia rufescens* (rare), and Palm was represented only by one species of *Pinanga*. Common

shrubs included *Ficus* sp., *Euchresta horsfieldii*, *Laportea* sp., *Leea indica*, *Saurauia* sp., *Psychotria viridiflora*, and *Villebrunea rufescens*. The epiphytes were represented by *Medinilla speciosa*, *Medinilla laevifolia*, *Rhododendron javanicum*, *Schefflera* sp., *Vaccinium* sp., a moss (*Usnea barbata*), orchids and ferns. The climbers were *Aeschynanthus radicans*, *Dischidia punctata*, *Elaeagnus latifolia*, *Ficus ruginervia*, *Freycinetia insignis*, *Phyllodendron* sp., *Piper chaba*, *Piper miniatum*, *Rubus* sp., and *Smilax odoratissima*. Rattans used to be abundant but had been harvested significantly. Herbs growing abundantly on moist places, and rocks along rivers, *Solanum* sp., ferns and orchids. A strange form of *Carica papaya*, which looked similar to *Vasconcellea pubescens* (synonym: *Carica candamarcensis*) of South America, was found here.

Photo: Wawan Sujarwo (2017)

Figure 3.41 Lower montane forest along the Beratan Lake at 1,500 masl is heavily disturbed by the landslides.

Photo: Wawan Sujarwo (2010)

Figure 3.42 A slightly disturbed montane forest around the open aquatic ecosystem of the Batur Lake, where floating and rooted herbaceous vegetation developed at the lake side.

On the upper section of Mount Batur, with the top at 1,771 masl, Kartawinata (1958) and Soepadmo (1961) noted that the landscape was still bare and montane forest was still in the early stage of succession after the last eruption many years ago and the rate of succession seemed very slow (Figure 3.43).

It was apparently due to the fact that there were no sources of propagules around the area and due to recurrent burning by local people during the dry season to stimulate the growth of young shoots to make them available for cattle to graze. On the upper slope up to the top the vegetation was sparse consisting of *Argyrea* sp., *Clematis aristata*, *Crotalaria albida*, *Buddleja asiatica*, *Ficus* sp., *Dodonaea viscosa*, *Lantana camara*, *Medinilla* sp., *Nothopanax cochleatus*,

Rubus sp., *Wendlandia* sp., *Vanda tricolor*, grasses, and ferns. Common pioneer tree species was *Casuarina junghuhniana* that grew sparsely on lava and sand.

Photo: Wawan Sujarwo (2010)

Figure 3.43 The landscape of montane forest on Mount Batur, where the forest is still in the early stage of succession, which seems to take place at a very slow rate.

The study on the secondary forest around Lake Batur, Kintamani, at the altitude of 1,200–1,300 masl (Figure 3.44) (Sujarwo & Darma, 2011), recorded 11 species and 10 families, with the total number of 98 individuals occurring in 0.24 ha sample plots. They were *Artocarpus heterophyllus*, *Casuarina junghuniana*, *Erythrina variegata*, *Eucalyptus urophylla*, *Helicia serrata*, *Ligustrum glomeratum*, *Mangifera indica*, *Melia azedarach*, *Paraserianthes falcataria*, *Pinus*

merkusii, and *Schima wallichii*. The dominant species was *Eucalyptus urophylla*, which together with *Pinus merkusii* and *Paraserianthes falcataria* were apparently planted in the area. *Eucalyptus urophylla* is not a native species to Bali although it was dominant and abundant here on the eastern side of the Lake Batur, *Schima wallichii* occurred on the southern side (Figure 3.45) and *Casuarina junghuhniana* on the western side.

Photo: Wawan Sujarwo (2010)

Figure 3.44 The secondary forest around Lake Batur, Kintamani at 1,050 masl, where the potential vegetation on the area is a lower montane forest.

Photo: Wawan Sujarwo (2010)

Figure 3.45 *Schima wallichii* is planted along the main road in Kintamani. In natural vegetation *Schima wallichii* occurs from wet lowland forest to montane forest up to about 2,000 masl.

One year after the eruption of Mount Agung (Figure 3.46) in February 1963, Dilmy (1965) wrote a short account on the early succession on lava deposited at the vicinity of the Besakih temple at the altitude of 900-1,250 masl. A total of 83 species of grasses, herbs, shrubs, were recorded as follows: *Ageratum conyzoides*, *Albizia montana*, *Albizia procera*, *Aleurites montana*, *Amaranthus spinosus*, *Anaphalis viscida*, *Areca catechu*, *Arenga pinnata*, *Artocarpus communis*, *A. elasticus*, *Averrhoa carambola*, *Boehmeria nivea*, *Caesalpinia pulcherrima*, *Callicarpa longifolia*, *Centella asiatica*, *Centotheca lappacea*, *Ceratopteris thalictroides*,

Cheiranthus tenuifolia, *Citrus maxima*, *Citrus* sp., *Clerodendrum serratum*, *Coffea arabica*, *Cordia dichotoma*, *Cynodon dactylon*, *Cyperus cyperoides*, *Cyperus rotundus*, *Davallia trichomanoides*, *Digitaria sanguinalis*, *Drymaria hirsuta*, *Elaeagnus latifolia*, *Eleusine indica*, *Engelhardia spicata*, *Equisetum debile*, *Erechtites valerianifolius*, *Erythrina variegata*, *Eugenia cumini*, *Eugenia polyantha*, *Euphorbia rothiana*, *Ficus ampelas*, *Ficus benjamina*, *Ficus septica*, *Fimbristylis quinquangularis*, *Flacourtia rukam*, *Gigantochloa apus*, *Hibiscus rosa-sinensis*, *Homalomena* sp., *Imperata cylindrica*, *Ipomoea batatas*, *Jatropha curcas*, *Rhynchospora colorata*, *Leucaena* sp., *Litsea* sp., *Lygodium japonicum*, *Melia azedarach*, *Michelia* sp., *Mirabilis jalapa*, *Musa* sp., *Nephelium* sp., *Paederia foetida*, *Paspalum conjugatum*, *Pennisetum purpureum*, *Plantago major*, *Pleomele elliptica*, *Persicaria chinensis*, *Pteridium revolutum*, *Ricinus communis*, *Saccharum spontaneum*, *Sambucus javanica*, *Schellolepis subauriculata*, *Sesbania grandiflora*, *Smilax leacophylla*, *Solanum torvum*, *Terminalia bellirica*, *Themeda gigantea*, *Toona sinensis*, *Vernonia arborea*, *Strobocalyx arborea*, *Viburnum lutescens*, *Viburnum sambucinum*, *Vitex trifolia*, and *Wedelia montana*. All the plants mentioned above covered only 10% of the area, the rest of the soil surface was still barren, as if the area had been cemented. At the altitude of 1,250 masl, *Pinus merkussii* trees in a plantation were all dead. At an elevation of 1,250 masl, several species were present here and there, including *Albizzia montana* tree, a bamboo *Gigantochloa apus*, the grass species *Cynodon dactylon*, *Imperata cylindrica*, *Pennisetum purpureum* and *Themeda gigantea*, an herb *Plantago major* and a small tree of *Sesbania grandiflora*.

Photo: Wawan Sujarwo (2009)

Figure 3.46 Mount Agung is viewed from Lempuyang Luhur Temple, showing the lower and upper montane forest cover and the man-made vegetation in the lower section.

O. Secondary Forest and Shrub

The secondary vegetation on dry land, known also as *belukar*, covers a large area in the province. It represents secondary growth of different ages, and has developed as the results of various human activities, including forest clear cutting, abandonment of cultivated lands, or leaving developing shrubs and grasslands undisturbed. Structurally it ranges from a simple young unistratal, mixed herbaceous, and woody plant community to a complex three-layered old secondary forest that will eventually develop into climax forest.

In the practice of slash and burn agriculture, there is a period of fallowing the lands after several years of cultivation. The fallowed land developed into young herb and shrub secondary communities and later into secondary forests. The composition of the secondary communities varies from one place to another, depending a great deal on the age, altitude, climate, soils, degree of destruction of the original vegetation, and the existence of surrounding vegetation as the source of propagules. The species composition of early successional communities and subsequent secondary forests cannot be generalized, but there are certain species known as pioneer species that build up the communities in the early stages of successions, which occur widely throughout Indonesia (Steenis, 1935a, 1935b; Steenis & Schippers-Lammerste, 1965). They include herbaceous species *Ageratum conyzoides*, *Ageratum houstonianum*, *Austroeupatorium inulifolium*, *Bidens pilosa*, *Imperata cylindrica*, *Erechtites hieracifolia*, *Saccharum spontaneum* then followed by woody shrubs and young trees *Antidesma montanum*, *Callicarpa* sp., *Commersonia* sp., *Celtis tetrandra*, *Clerodendrum serratum*, *Debregeasia* sp., *Decaspermum fruticosum*, *Dillenia* sp., *Ficus* spp., *Glochidion* sp., *Grewia* spp., *Helicteres hirsuta*, *Helicteres viscida*, *Hibiscus grewiifolius*, *Homalanthus* sp., *Ixora fulgens*, *Kleinhovia hospita*, *Lantana camara*, *Macaranga* spp., *Mallotus* sp., *Melastoma* sp., *Mussaenda* sp., *Pavetta indica*, *Piper aduncum*, *Tetracera indica*, *Trema orientalis*, *Vitex* spp., *Villebrunea* sp., *Uncaria* sp. (Steenis, 1935a, 1935b; Steenis & Schippers-Lammerste, 1965).

From data available (e.g. Steenis, 1935a, 1935b; Steenis et al., 1972; Whitmore, 1986), the followings are the typical secondary tree species occurring in seasonal monsoon successional forests, i.e., *Acacia leucophloea*, *Acacia tomentosa*, *Aegle marmelos*, *Albizia chinensis*, *Albizia lebekkoides*,

Azadirachta indica, *Banksia* sp., *Borassus flabellifer*, *Butea monosperma*, *Caesalpinia digyna*, *Cassia fistula*, *Casuarina junghuhniana*, *Corypha utan*, *Dalbergia latifolia*, *Dichrostachys cinerea*, *Dodonaea viscosa*, *Engelhardia spicata*, *Eucalyptus alba*, *Eucalyptus* spp., *Feronia limona*, *Garuga floribunda*, *Glochidion obscurum*, *Homalanthus giganteus*, *Homalanthus tomentosum*, *Lannea grandis*, *Melia azedarach*, *Santalum album*, *Schleichera oleosa*, *Schoutenia ovata*, *Stereospermum suaveolens*, *Streblus asper*, *Tamarindus indica*, *Tectona grandis*, *Tetrameles nudiflora*, *Vernonia arborea* and *Weinmannia blumei*.

Shrubs developed as a result of forest clearing, fire and abandonment of cultivated lands. *Imperata cylindrica* and other pioneer species may invade such areas. Recurrent fires, absence of propagules and forests in the immediate surrounding areas prevent the successions to take place thus perpetuating the existence of *Imperata* grasslands and scrubs as 'permanent' communities. They cover relatively extensive areas in Indonesia. Shrubs are composed of grasses, herbs, and ferns that form an integrated unit in the vegetation of Indonesia and cover extensive areas (Steenis, 1935a, 1935b), which may form a variety of landscapes. They are relatively heterogeneous and may possess secondary features and structurally they form impenetrable communities. The majority of species are low in stature, and tree species may be present but scattered in the communities, thus creating savannas. A good example of scrubs are grazing lands commonly occur in the vicinity of settlements and villages elsewhere in Indonesia. Here in addition to *Imperata cylindrica*, other grass species, herbs and shrubs, are common in the community such as *Ageratum conyzoides*, *Bidens pilosa*, *Brucea amarissima*, *Clerodendrum serratum*, *Austroeupatorium inulaefolium*, *Lantana camara*, *Psychotria malayana*, *Saccharum spontaneum*, *Tetracera indica*, etc. (Steenis, 1935a, 1935b, 1975).

Ethnobotany of Bali's Signature Vegetation

Ethnobotany falls within the knowledge and practices concerning nature and the universe, which constitute humanity's intangible cultural heritage, as defined by UNESCO in 2003. This declaration was fundamental towards the recognition of orally transmitted traditional knowledge systems as an integral part of cultural heritages needing protection (Kurin, 2004; Vecco, 2010).

Bali is the island where the Balinese mostly live. The Balinese are one of the three large tribes within the Austronesians; the others are the Javanese and Sundanese. Compared with the other two tribes, the Balinese have long been regarded as unique for being the predominantly non-Muslim society surrounded by Muslims in one of the largest Muslim countries, Indonesia. Thus, the Balinese are one of the few tribes found in Indonesia, which is the largest Austronesian nation, who somehow still preserve most of the pre-Islamic Austronesian culture.

In fact, despite the majority of them being Hindus, the Hinduism practiced in Bali is fairly different from the original Indian Sanskrit-based Hinduism in India (Sujarwo et al., 2015; Sujarwo et al., 2017; Sujarwo et al., 2020). Regarding the use of certain species of plants, the Balinese implement many of them in their religious ritual, which is unknown or has never been seen practiced in India, such as the usage of

the common pandan or *Pandanus tectorius* (Pandanaceae) (Keim et al., 2020).

Pandanus tectorius is regarded as sacred in Balinese culture, also in its closely related ethnic groups, the Javanese and Sundanese (Keim et al., 2020) (Figure 4.1). On the contrary, the species has never been seen or recorded to be incorporated in the religious or religion-related practices in India. Thus, it is suggested here that the Hinduism practiced in Bali is basically the indigenous Austronesian belief (with indigenous species of plants involved) tinted with the imported Indian Hinduism. This fact even uplifts Bali as an exceptionally fascinating place for the study of Austronesian civilization on intangible cultural heritage, due to the valuable non-material cultural heritage, which is still lively practiced in Balinese daily life (Table 4.1).

Photo: Ary Prihardhyanto Keim (2014)

Figure 4.1 *Pandanus tectorius* is always planted in the Balinese Hindu temples or shrines as can be seen here in Delot Berawah, Jembrana.

Table 4.1 Ethnobotanical Plants from the Island of Bali

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Acanthaceae			
Acanthus ebracteatus Vahl (**Herb**)	Jeruju	Ripe fruit eaten fresh	Malesian, Northeastern Australian
Andrographis paniculata (Burm. f.) Nees (**Shrub**)	Sambilata	Leaf decoction for fever, hypertension, urolithiasis, diarrhea, malaria, diabetes	Indian
Barleria lupulina Lindl. (**Shrub**)	Landep	The leaf juice is applied to the skin as venom antidote and for sprains	Madagascan
Graptophyllum pictum (L.) Griff. (**Shrub**)	Temen	Leaf decoction for fever, cough; Juice of leaves is applied to the skin for skincare benefits	Malesian
Rhinacanthus nasutus (L.) Kurz (**Shrub**)	Manukan	The leaf juice is applied to the skin for skincare	Indian
Strobilanthes crispa Blume (**Shrub**)	Pecah beling, keji beling	Leaf decoction to cure kidney stones	Madagascan
Adoxaceae			
Sambucus javanica Blume (**Shrub**)	Gegirang, sangitan	The juice of the whole plant is applied to the skin for wounds and dermatitis	Indian, Indochinese, Malesian
Amaranthaceae			
Amaranthus blitum L. (**Herb**)	Bayem kedis	Cooked leaves added to vegetable soups	Mediterranean

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Aerva sanguinolenta (L.) Blume (**Shrub**)	Bayem barak	The decoction of young leaves and stems is for diabetes and to regulate menstrual cycle	Indian, Indochina, Malesian
Celosia argentea L. (**Herb**)	Daun kepotpot	The cooked leaves added to vegetable soups	Guineo-Congolian, Usambara-Zululand, Sudano-Zambezian, Madagascan
Anacardiaceae			
Mangifera caesia Jack (**Tree**)	Wani	Ripe fruit eaten fresh	Malesian
Mangifera indica L. (**Tree**)	Mangga	Leaf decoction for diabetes and hypertension	Indian
Mangifera odorata Griff. (**Tree**)	Poh pakel	Ripe fruit eaten fresh	Malesian
Spondias pinnata (L. f.) Kurz (**Tree**)	Kecemcem, cemceman	Leaf juice for heartburn, urolithiasis, diabetes	Indochinese, Indian, Malesian
Annonaceae			
Annona muricata L. (**Shrub**)	Sirsak	Ripe fruit eaten fresh	Andean, Caribbean, Chaco, Llanos, Mexico
Annona squamosa L. (**Shrub**)	Silik	Ripe fruit eaten fresh	Amazonian, Andean, Brazilian, Caribbean, Region of the Guayana Highland

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Apiaceae			
Centella asiatica (L.) Urb. (**Herb**)	Paiduh	Leaf decoction for cough, fever, heartburn, diarrhea, aphthous stomatitis, sore throat, dysentery, diabetes, bronchitis, haemorrhoids, and for increasing memory	Indian, Malesian
Apocynaceae			
Alstonia scholaris (L.) R. Br. (**Tree**)	Pule	Raw sap used for treating malaria; the leaf decoction is used for diarrhea, fever, heartburn, and for stimulating the appetite; decoction of bark used as a diuretic, for treating infections, heartburn, diarrhea,	Indochinese, Malesian, Northeastern Australian
Alstonia scholaris (L.) R. Br. (**Tree**) (cont'd)	Pule	rheumatic pain, cough, malaria, and to stimulate appetite	Indochinese, Malesian, Northeastern Australian
Cascabela thevetia (L.) Lippold (**Shrub**)	Palit sedangan, ginje	Leaf juice for sore eyes or eye strain	Caribbean, Malesian, Madrean

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Plumeria alba L. (**Shrub**)	Jepun, kamboja putih	The flowers juice is applied to the skin for smallpox	Caribbean
Sarcostemma esculentum (L.f) R.W.Holm (**Herb**)	Daun pepe	Cooked leaves added to vegetable soups	Northeastern Australian
Araceae			
Alocasia macrorrhiza (L.) G.Don (**Herb**)	Sente	Boiled tuberous roots eaten as a staple food; Ripe fruit eaten fresh	Malesian, Northeastern Australian
Amorphophallus campanulatus (Roxb.) Bl.ex Decne (**Herb**)	Suweg	Boiled tuberous roots eaten as a staple food	Indian, Malesian
Colocasia esculenta (L.) Schott (**Herb**)	Keladi putih	Boiled tuberous roots eaten as a staple food; Cooked leaves added to vegetable soups	Malesian
Colocasia gigantea (Bl.) Hook.f. (**Herb**)	Candung	Boiled tuberous roots eaten as staple food	Indochinese, Malesian
Xanthosoma sagittifolium (L.) (**Shrub**)	Keladi selem, talas belitung	The rhizomes juice is applied to the skin as a skincare	Amazonian, Andean, Brazilian, Caribbean, Region of the Guayana Highlands
Araliaceae			
Hydrocotyle sibthorpioides Lam (**Herb**)	Semanggi	Leaf decoction to stimulate appetite	Indochinese, Malesian

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Schefflera aromatica (Blume) Harms. (**Tree**)	Gembal jaran	Cooked leaves added to vegetable soups	Malesian
Trevesia sundaica Miq. (**Tree**)	Daun pelindo	Leaf decoction for heartburn	Malesian
Arecaceae			
Areca cathecu L. (**Tree**)	Pinang, Buah jambe	Ripe fruit eaten fresh for stomach problems and coughing	Malesian
Arenga pinnata (Wurmb) Merr. (**Tree**)	Aren	Boiled inner stems eaten as a staple food; Roots decoction for urolithiasis; Edible boiled fruit	Malesian, Indian
Borassus flabellifer L. (**Tree**)	Ental	Ripe fruit eaten fresh	Malesian, Indian
Calamus reinwardtii Bl. (**Woody climber**)	Rotan	Cooked leaf tips added to vegetable soups	Malesian
Livistona rotundifolia (Lamk.) Mart. (**Tree**)	Daun ibong	Cooked leaves added to vegetable soups	Malesian
Salacca zalacca (Gaertn.) Voss (**Shrub**)	Salak	Ripe fruit eaten fresh	Malesian
Asparagaceae			
Cordyline fruticosa (L.) A.Chev (**Shrub**)	Andong	Roots decoction for stamina increase and diarrhea	Indian, Indochinese, Malesian

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Cordyline rubra Otto & A.Dietr. (**Shrub**)	Andong merah	Leaf decoction for heartburn	Northeast Australian
Asteraceae			
Blumea balsamifera (L.) DC. (**Shrub**)	Daun sembung	Leaf decoction for diarrhea, fever, heartburn, constipation, bronchitis	Indian, Indochinese, Malesian
Cyanthillium cinereum (L.) H.Rob. (**Shrub**)	Sembung sotong	Leaf decoction for heartburn, and to stimulate appetite	Indian, Malesian, Sudano-Zambesian
Gynura aurantiaca (Bl.) DC. (**Herb**)	Celengot, umyung	Cooked young leaves added to vegetable soups; The decoction of young stems	Malesian
Gynura aurantiaca (Bl.) DC. (**Herb**) (cont'd)	Celengot, umyung	and leaves is for liver problems and hepatitis	Malesian
Gynura procumbens (Lour.) Merr. (**Climber**)	Sembung dewa	Cooked leaves added to vegetable soups	Indochinese, Malesian
Basellaceae			
Anredera cordifolia (Tenore) Steen. (**Climber**)	Winahong	Cooked leaves added to vegetable soups	Amazonia, Andean, Brazilian, Region of the Guayana Highlands

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Blechnaceae			
Blechnum orientale L. (**Herb**)	Paku jahe	Cooked leaves added to vegetable soups	Indian, Indochinese, Malesian, Northeast Australian, Southwest Australian
Cactaceae			
Epiphyllum crenatum (Lindl.) G. Don (**Succulent**)	Wijaya kusuma	Flower decoction for hepatitis	Caribbean, Madrean
Caricaceae			
Carica papaya L. (**Tree**)	Gedang	Cooked fruit and young leaves added to vegetable soups	Caribbean
Casuarinaceae			
Casuarina junghuhniana Miq. (**Tree**)	Cemara geseng	Sap decoction for diarrhea	Malesian
Clusiaceae			
Garcinia dulcis (Roxb.) Kurz (**Tree**)	Mundeh	Ripe fruit eaten fresh	Malesian
Garcinia mangostana L. (**Tree**)	Manggis	Ripe fruit eaten fresh	Malesian
Garcinia parvifolia (Miq.) Miq. (**Tree**)	Badung	Ripe fruit eaten fresh	Malesian

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Convolvulaceae			
Ipomoea batatas (L.) Poir. (**Climber**)	Ketela rambat	Cooked leaves added to vegetable soups	Amazonian, Andean, Brazilian, Caribbean, Region of the Guyana Highlands
Ipomoea pes-caprae (L.) R.Br (**Climber**)	Daun katang-katang	Cooked leaves added to vegetable soups	Atlantic and Gulf Coastal Plain, Indian, Madagascan, Malesian, Northeastern Australian, Southwest Australian, Zanzibar-Inhambane
Cucurbitaceae			
Coccinia grandis (L.) Voigt (**Climber**)	Paspasan	Cooked leaves added to vegetable soups	Indian
Cucurbita moschata (Duch.) Poir. (**Climber**)	Labu	Cooked fruit and leaves added to vegetable soups	Caribbean, Region of the Guayana Highlands
Luffa acutangula (L.) Roxb. (**Climber**)	Pare	Cooked leaves added to vegetable soups; Edible boiled seeds	Eastern Asiatic, Malesian
Momordica charantia L. (**Climber**)	Paya puuh	Cooked fruit added to vegetable soups; Leaf decoction for heartburn	Indian

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Sechium edule (Jacq.) Sw. (**Climber**)	Labu siam	Cooked fruit and leaves added to vegetable soups	Caribbean
Dioscoreaceae			
Dioscorea alata L. (**Climber**)	Serbet	Boiled tuberous roots eaten as staple food	Fijian, Hawaiian, Polynesian
Dioscorea esculenta (Lour.) Burk (**Climber**)	Ubi aung	Boiled tuberous roots eaten as staple food	Madagascan, Sudano-Zambesian, Uzambara-Zululand
Dioscorea hispida Dennst. (**Climber**)	Gadung	Boiled tuberous roots eaten as staple food	Indian, Indochinese, Malesian
Elaeocarpaceae			
Elaeocarpus sphaericus (Gaertn.) K.Schum. (**Tree**)	Genitri	Ripe fruit eaten fresh	Indian, Indochinese, Malesian, North-eastern Australian
Euphorbiaceae			
Aleurites moluccanus (L.) Willd. (**Tree**)	Tingkih	Fruit used as spices	Malesian
Antidesma bunius (L.) Spreng. (**Tree**)	Buni	Leaf decoction for fever and diarrhea; Ripe fruit eaten fresh	Malesian, North-eastern Australian
Baccaurea racemosa (Reinw.ex Bl.) M.A. (**Tree**)	Kepundung	Ripe fruit eaten fresh	Malesian
Bischofia javanica Bl. (**Tree**)	Gintungan	Ripe fruit eaten fresh	Indochinese, Indian, Malesian

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Cicca acida (L.) Merr. (**Tree**)	Cermei	Ripe fruit eaten fresh	Madagascan
Jatropha curcas L. (**Shrub**)	Jarak	Leaf decoction for diarrhea, diuretic; Sap paste used for aphthous stomatitis	Andean
Jatropha integerrima Jacq. (**Shrub**)	Batavia	Sap is applied to the teeth for dental care	Caribbean
Manihot esculenta Crantz (**Shrub**)	Singkong	Cooked young leaves added to vegetable soups	Brazilian
Phyllanthus urinaria L. (**Herb**)	Isep getih, meniran	Leaf decoction for diarrhea	Eastern Asiatic, Indian, Indochinese, Malesian
Fabaceae			
Cajanus cajan (L.) Millsp. (**Shrub**)	Undis	Cooked seeds added to vegetable soups	Indian
Erythrina hypaphorus Boerl. (**Tree**)	Dadap tis	Cooked young leaves added to vegetable soups; Leaf decoction for heartburn	Malesian, Indian
Erythrina subumbrans (Hassk.) Merr. (**Tree**)	Dadap	Cooked leaves added to vegetable soups	Malesian, Indian
Euchresta horsfieldii (Lesch.) Benn. (**Shrub**)	Purnajiwa	Ripe seed eaten fresh as a health tonic for stamina increase	Indian, Indochinese, Malesian

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Lablab purpureus subsp. *purpureus* **(Climber)**	Komak	Cooked leaves and seeds added to vegetable soups; Leaf decoction for fever, cough, and diarrhea; Edible boiled seeds	Guineo-Congolian
Phaseolus lunatus L. **(Climber)**	Buncis	Cooked leaves and seeds added to vegetable soups	Andean
Phaseolus vulgaris L. **(Climber)**	Kacang lilit	Cooked leaves and seeds added to vegetable soups	Andean
Pueraria phaseoloides (Roxb.) Bth. **(Climber)**	Ucu	Cooked seeds added to vegetable soups	Malesian
Psophocarpus tetragonolobus (L.) DC. **(Climber)**	Kecipir	Cooked young fruit added to vegetable soups	Indian, Indochinese, Malesian
Tamarindus indica L. **(Tree)**	Asem	Cooked leaves and fruit added to vegetable soups; Ripe fruit eaten fresh	Sudano-Zambesian
Heliconiaceae			
Heliconia wagneriana Petersen **(Shrub)**	Pisang bunga	Ripe fruit eaten fresh	Madrean
Lamiaceae			
Clerodendrum buchananii (Roxb.) Walp. **(Tree)**	Kembang agoda	The roots juice is applied to the skin for rheumatism	Indian, Malesian

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Coleus parviflorus Bth. (**Herb**)	Sabrang	Boiled tuberous roots eaten as a staple food	Indian
Elsholtzia elata Z. & M. (**Shrub**)	Jungul	Cooked leaves added to vegetable soups	Indochinese, Malesian
Hyptis capitata Jacq. (**Shrub**)	Bube, rumput knop	The leaf juice is applied to the skin as skincare	Caribbean, Madrean
Mentha arvensis L. (**Herb**)	Daun poko	Leaf decoction for diarrhea	Eastern Asiatic, Indian, Irano-Turanian, Mediterranean, North American Atlantic
Ocimum basilicum L. (**Shrub**)	Kemangi	Cooked leaves added to vegetable soups	Indian
Orthosiphon aristatus (Blume) Miq. (**Shrub**)	Kumis kucing	The decoction of leaves and flowers used as a diuretic, and to treat hypertension, and urolithiasis	Indian, Indochinese, Malesian, Northeastern Australian
Salvia splendens Sellow ex Schult. (**Herb**)	Salvia merah	The leaf juice is applied to the skin as skincare	Brazilian
Vitex trifolia L. (**Shrub**)	Lili gundi	Leaf decoction for skin allergies; the leaf juice is applied to the skin to increase the body heat	Eastern Asiatic, Indian, Indochinese, Malesian, Northeast Australian, Sudano-Zambezian

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Lauraceae			
Cinnamomum burmanni Nees ex Bl. (**Tree**)	Kayu manis	Barks used as spices; Leaf and barks decoction used for heartburn, fever, cough, sore throat, hypertension, and to stimulate appetite	Malesian
Cinnamomum sintoc Blume (**Tree**)	Sintok	Bark paste is applied to the skin for swelling and wounds	Indochinese, Malesian
Persea americana Mill. (**Tree**)	Apokat	Cooked young fruit added to vegetable soups	Caribbean
Lecythidaceae			
Planchonia valida (Blume) Blume (**Tree**)	Kutat, putat	Bark juice for stamina increase	Malesian
Lygodiaceae			
Lygodium circinatum (Burm. f.) Sw. (**Climber**)	Paku ata	The leaf decoction is used as a preventive medicine after labor	Indochinese, Indian, Malesian, Northeastern Australian
Lythraceae			
Punica granatum L. (**Shrub**)	Delima	Ripe fruit eaten fresh; Decoction of roots, fruit, and leaf sap used for dysentery	Irano-Turanian

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Malvaceae			
Gossypium herbaceum L. (**Shrub**)	Kapas bali	Eible boiled young fruit	Saharo-Arabian
Hibiscus rosa-sinensis L. (**Shrub**)	Daun pucuk, kembang sepatu	Decoction of young leaves to facilitate labor process; Leaf juice is also used to facilitate labor process	Eastern Asiatic
Hibiscus sabdariffa L. (**Shrub**)	Rosela	Flower decoction for heartburn	Guineo-Congolian
Hibiscus schizopetalus (Dyer) Hook.f. (**Shrub**)	Kembang sepatu gantung	Leaf juice to facilitate labor process and treat heartburn	Uzambara-Zululand
Hibiscus syriacus L. (**Shrub**)	Bunga Sharon	Leaf juice to facilitate labor process and as a hair care	Eastern Asiatic
Hibiscus tilliaceus L. (**Tree**)	Waru	The leaf juice is used for dysentery, fever, and to facilitate labor process	Polynesian
Sida rhombifolia L. (**Shrub**)	Selegui	The roots decoction is used for beriberi, and cough with phlegm	Eastern Asiatic, Guineo-Congolian, Indian, Indochinese, Malesian, Sudano-Zambesian, Uzambara-Zululand

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Marantaceae			
Maranta arundinacea L. (**Herb**)	Arus	Boiled tuberous roots eaten as a staple food; Rhizome decoction for heartburn	Amazonian, Brazilian, Caribbean, Madrean, Region of the Guayana Highlands
Pleiostachya pruinosa (Regel) K.Schum. (**Herb**)	Maranta	The juice of roots, stems, and young leaves is applied to the skin for rheumatism and as skincare	Caribbean, Madrean
Melastomataceae			
Medinilla speciosa Blume (**Shrub**)	Trijata, parijoto	Fruit juice for stamina increase	Malesian
Melastoma malabathricum L. (**Shrub**)	Kedukduk, senduduk	The leaf juice is applied to the skin as skincare	Eastern Asiatic, Indian, Indochinese, Malesian, Northeast Australian
Meliaceae			
Azadirachta indica A. Juss. (**Tree**)	Intaran, mimba, mimbo	The decoction of leaves, barks, and fruits is used as a diuretic and for heartburn, diabetes, headache, and to stimulate appetite	Indian

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Lansium domesticum Corr. (**Tree**)	Ceroring	Ripe fruit eaten fresh	Malesian
Sandoricum koetjape (Burm.f) Merr. (**Tree**)	Sentul	Ripe fruit eaten fresh	Malesian
Menispermaceae			
Anamirta cocculus (L.) Wight & Arn. (**Climber**)	Kantawali	Stem decoction for diarrhea	Indian, Malesian
Cyclea barbata Miers (**Climber**)	Daluman kebo, sidaluman	Leaf decoction for fever, nausea, heartburn, headache	Indochinese, Eastern Asiatic, Malesian
Moraceae			
Artocarpus elasticus Reinw.ex Bl. (**Tree**)	Teep	Edible boiled seeds; Ripe fruit eaten fresh	Malesian, Indochinese
Artocarpus heterophyllus Lmk (**Tree**)	Nangka	Cooked young fruit and seeds added to vegetable soups; Leaf decoction for diarrhea	Malesian, Indian
Ficus drupacea Thunb. (**Tree**)	Bunut	Bark decoction for rheumatic pain and heartburn	Malesian, Northeastern Australia
Ficus fistulosa Reinw. ex Bl. (**Tree**)	Daun dadem	Cooked leaves added to vegetable soups	Malesian, Indian, Indochinese

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Ficus quercifolia Blume (**Tree**)	Uyah-uyah	The juice of aerial roots is applied to the skin as an antidote	Malesian
Morus alba L. (**Shrub**)	Kayu besar, besaran	Cooked leaves added to vegetable soups; Leaf decoction for hypertension and as a diuretic; Roots decoction for dental care	Eastern Asiatic
Moringa oleifera Lam. (**Tree**)	Kelor	Cooked leaves and fruits added to vegetable soups	Indian
Musaceae			
Musa brachycarpa Back. (**Herb**)	Pisang batu	Cooked core stems added to vegetable soups	Malesian
Musa paradisiaca L. (**Herb**)	Pisang	Cooked core stems added to vegetable soups	Indochinese, Indian, Malesian
Myrtaceae			
Psidium guajava L. (**Shrub**)	Sotong	Ripe fruit eaten fresh	Caribbean, Madrean
Syzygium cumini (L.) Skeels (**Tree**)	Juwet	Ripe fruit eaten fresh	Indian, Malesian
Syzygium polyanthum (Wight) Walp. (**Tree**)	Salam, jangar ulam	Leaf juice for stomachache and diarrhea; Leaves used as spices; Ripe fruit eaten fresh	Indochinese, Malesian

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Syzygium polycephalum (Miq.) Merr.&Perry (**Tree**)	Kaliasem	Ripe fruit eaten fresh	Malesian
Syzygium samarangense (Blume) Merrill & Perry (**Tree**)	Jambu merah	Leaf tips decoction for diarrhea; Ripe fruit eaten fresh	Malesian
Nyctaginaceae			
Mirabilis jalapa L. (**Herb**)	Kembang sore, bunga pukul empat	Flower decoction for stamina increase	Caribbean, Madrean
Oxalidaceae			
Averrhoa bilimbi L. (**Tree**)	Belimbing buluh	Cooked fruit and leaves added to vegetable soups; Ripe fruit eaten fresh	Malesian
Averrhoa carambola L. (**Tree**)	Belimbing besi	Cooked fruit and leaves added to vegetable soups; Leaf juice for heartburn	Indian, Malesian
Pandanaceae			
Pandanus amaryllifolius Roxb. (**Shrub**)	Pandan wangi	Leaf decoction for rheumatism and to relax nerves	Malesian

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Pandanus tectorius Parkinson ex Du Roi	Pandan, pandan laut, pandan lot, pudak, pudak duri	The presence of phenolic compounds, including flavonoids and caffeoylquinic acids, indicates that the fruits have antioxidant, antibacterial, anti-diabetic, a-glucosidase inhibitory, and antidiarrheal attributes.	Malesian
Phyllanthaceae			
Phyllanthus niruri L. (**Herb**)	Kemeniran, menirang	Leaf decoction for fever, and treating kidney stones	Amazonian, Andean, Brazilian, Caribbean, Madrean, Region of the Guayana Highlands,
Sauropus androgynus (L.) Merr. (**Shrub**)	Daun katuk	Cooked leaves added to vegetable soups; leaf decoction for heartburn, and removal of waste products from the blood	Malesian

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Piperaceae			
Piper betle L. (**Climber**)	Sirih	Cooked leaves added to vegetable soups; leaf decoction for body odor, diarrhea, sore throat, skin allergies, fluor albus	Malesian
Piper cubeba L.f. (**Climber**)	Kemukus	Cooked leaves added to vegetable soups	Malesian
Plumbaginaceae			
Plumbago zeylanica L. (**Shrub**)	Bama, daun encok	The roots juice is applied to the skin for rheumatism and as skincare	Indian, Malesian, Northeastern Australian
Poaceae			
Coix lacryma-jobi L. (**Grass**)	Jali-jali	Seeds decoction for diarrhea and seed paste is applied to the skin as skincare	Malesian
Dendrocalamus asper (Schult.) Backer (**Tree**)	Petung	Cooked young shoots added to vegetable soups	Malesian
Gigantochloa apus (Schult.) Kurz (**Tree**)	Bambu tali	Cooked young shoots added to vegetable soups	Indian, Indochinese, Malesian
Gigantochloa nigrociliata (Buse) Kurz (**Tree**)	Bambu tabah	Cooked young shoots added to vegetable soups	Indian, Indochinese, Malesian

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Saccharum officinarum L. (**Shrub**)	Tebu	Stem sap used for cough	Indian, Indochinese, Malesian
Schizostachyum lima (Blanco) Merr. (**Tree**)	Buluh	Cooked young shoots added to vegetable soups	Malesian
Podocarpaceae			
Dacrycarpus imbricatus (Blume) de Laub. (**Tree**)	Cemara pandak	Sap decoction for diarrhea	Indochinese, Malesian, Fijian
Primulaceae			
Ardisia crenata Sims (**Shrub**)	Mata ayam	Ripe fruit eaten fresh for endurance and stamina	Indian, Indochinese, Malesian
Ardisia humilis Vahl (**Shrub**)	Lempeni	Ripe fruit eaten fresh for endurance and stamina	Indochinese, Malesian
Rosaceae			
Rubus alpestris Bl. (**Climber**)	Gunggung	Ripe fruit eaten fresh	Indian, Indochinese, Malesan
Rubus calycinus Wall.ex D.Don (**Climber**)	Gunggung	Ripe fruit eaten fresh	Indian
Rubus chrysophyllus Reinw.ex. Miq. (**Climber**)	Gunggung	Ripe fruit eaten fresh	Malesian, Northeastern Australian
Rubus fraxinifolius Poir. (**Climber**)	Gunggung	Ripe fruit eaten fresh	Malesian
Rubus lineatus Reinw.ex Bl. (**Climber**)	Gunggung	Ripe fruit eaten fresh	Indian, Malesian

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Rubus rosaefolius J.E. Smith (**Shrub**)	Gung-gung	Ripe fruit eaten fresh	Indian , Indochinse, Malesian, Northeastern Australian
Rubiaceae			
Coffea robusta L. Linden (**Small tree**)	Kopi robusta	Decoction of seeds powder to induce relaxation	Guineo-Congolian
Gardenia jasminoides J. Ellis (**Shrub**)	Jempiring	Leaf decoction as a diuretic; leaf juice to facilitate labor process	Eastern Asiatic
Paederia foetida L. (**Climber**)	Kesimbukan, simbukan, daun kentut	Cooked leaves added to vegetable soups; leaf decoction for fever, and to stimulate appetite; The water collected inside the stem is used to treat aphthous stomatitis	Eastern Asiatic
Rutaceae			
Boenninghausenia albiflora (Hook.) Rchb. Ex Meisn. (**Shrub**)	Ingu, kelor hutan	Leaf decoction for fever, rheumatism, and heartburn	Indian, Indochinese, Malesian
Citrus amblycarpa (Hassk.) Ochse (**Tree**)	Limo	Fruit and leaves used as spices	Malesian
Citrus aurantiifolia (Christm.) Swingle (**Shrub**)	Jeruk nipis	Fruit juice used for cough	Indian

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Citrus grandis (L.) Osbeck (**Tree**)	Jeruk bali	Ripe fruit eaten fresh	Malesian
Salicaceae			
Flacourtia inermis Roxb. (**Shrub**)	Lubi	Ripe fruit eaten fresh	Malesian
Pangium edule Reinw. (**Tree**)	Pangi	Ripe fruit eaten fresh	Malesian
Sapindaceae			
Schleichera oleosa (Lour.) Oken (**Tree**)	Kesambi	Ripe fruit eaten fresh	Malesian, Indian
Nephelium lappaceum L. (**Tree**)	Rambutan	Ripe fruit eaten fresh	Malesian
Sapotaceae			
Chrysophyllum cainito L. (**Tree**)	Nyeleket	Ripe fruit eaten fresh	Caribbean
Manilkara zapota (L.) P.Royen (**Tree**)	Sawo	Ripe fruit eaten fresh	Caribbean
Simaroubaceae			
Picrasma javanica Blume (**Tree**)	Melela	Bark decoction for heartburn	Indochinese, Malesian
Solanaceae			
Cyphomandra betacea (Cav.) Miers. (**Shrub**)	Terong belanda	Fruit juice for aphthous stomatitis, hypertension; Ripe fruit eaten fresh	Andean
Solanum nigrum L. (**Herb**)	Anti	Cooked leaves added to vegetable soups; Ripe fruit eaten fresh	Circumboreal, Eastern Asiatic, Indian, Irano-Turanian, Mediterranean

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Thelypteridaceae			
Pneumatopteris callosa (Blume) Nakai (**Shrub**)	Paku lindung	Cooked leaves added to vegetable soups; Leaf decoction for fever, and hypertension	Malesian
Thymelaeaceae			
Phaleria octandra (L.) Baill. (**Shrub**)	Mut	Decoction of dried ripen fruits for hypertension and liver cancer; leaf decoction for cervical cancer	Malesian, Northeastern Australian
Urticaceae			
Dendrocnide stimulans (L.f.) Chew (**Tree**)	Lateng kidang	Ripe fruit eaten fresh; the water inside the root used to treat sprue	Malesian, Indochinese
Verbenaceae			
Stachytarpheta indica (L.) Vahl (**Shrub**)	Pecut kuda	Leaf decoction for tonsillitis	Amazonian, Brazilian, Caribbean, Madrean, Region of the Guayana Highlands
Woodsiaceae			
Diplazium esculentum (Retz.) Swartz (**Shrub**)	Paku jukut	Cooked young leaves added to vegetable soups	Indian, Indochinese, Malesian
Diplazium repandum Bl. (**Shrub**)	Paku udang	Cooked young leaves added to vegetable soups	Malesian

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Xanthorrhoeaceae			
Aloe vera (L.) Burm.f. (**Succulent**)	Lidah buaya	*Aloe vera* gel paste is applied to the skin as skincare (skin rejuvenation, anti-acne, sunburn, and hair care (shampoo), while the juice of *Aloe vera* leaves is used as a diuretic	Sudano-Zambesian
Zingiberaceae			
Amomum maximum Roxb. (**Herb**)	Kapulaga	Ripe fruit used as spices	Malesian, Indochinese
Cheilocostus speciosus (J. Koenig) C. D. Specht (**Herb**)	Ubi kayu tawa	Leaf decoction for fever	Indochinese, Indian, Malesian, Northeastern Australian
Curcuma domestica Valeton (**Herb**)	Kunyit	Cooked young leaves added to vegetable soups; rhizomes used as spices	Indian
Curcuma purpurascens Blume (**Herb**)	Temu tis	Rhizomes juice used to cleanse the blood after labor	Malesian
Curcuma sylvatica Valeton (**Herb**)	Temu-temuan	Rhizomes juice for stamina increase	Malesian
Curcuma zanthorrhiza Roxb. (**Herb**)	Temu agung	Rhizomes sap used for heartburn	Malesian

Plant families & Species (Life Form)	Vernacular Names	Parts Used & Uses	Floristic Region
Kaempferia galanga L. (**Herb**)	Cekuh	Cooked rhizomes and young leaves added to vegetable soups; Rhizomes used as spices	Indochinese, Indian, Malesian
Kaempferia rotunda L. (**Herb**)	Kunci	Leaf decoction for rheumatism, and to increase body heat; Cooked rhizomes and young leaves added to vegetable soups	Indian
Languas galanga (L.) Stuntz (**Herb**)	Lengkuas	Rhizomes used as spices	Malesian, Indian
Nicolaia speciosa (Bl.) Horan (**Herb**)	Kecicang	Rhizomes used as spices Cooked flowers added to vegetable soups	Malesian
Zingiber officinale Roscoe (**Herb**)	Jahe	Rhizomes used as spices; Rhizomes decoction used for cough, rheumatism, headache, and to increase body heat	Indian
Zingiber purpureum Roxb. (**Herb**)	Gamongan	Cooked rhizomes and young leaves added to vegetable soups	Malesian
Zingiber zerumbet (L.) Roscoe ex Smith (**Herb**)	Bangle, banglai	Rhizomes juice for constipation and abscesses	Eastern Asiatic, Indochinese, Indian, Malesian

Source: Sujarwo et al. (2015); Sujarwo and Caneva (2015); Sujarwo et al. (2016)

A. Medicinal Plants

The field of medicinal plants now seems highly relevant to improve biodiversity application in medicinal culture. We were impressed by the traditional Chinese medicine, whose application in modern medicinal research led a researcher, Dr. Tu Youyou, to winning the Nobel Prize in Physiology or Medicine 2015, for her discoveries through a novel therapy against Malaria. This success resulted when an ancient text revealed a method of using *qinghao*, the Chinese name for sweet wormwood, to extract artemisinin. On the other hand, the use of modern medicines and pharmaceuticals has spoiled humans to the extent of declining knowledge of ancestral traditional medicines. Even though people are interested in 'back to nature' drives, the price of medicines in Indonesia is increasing and there is a dependence on imported medicines. Therefore, an Indonesian development plan conceived many years ago which contained a program that has partly focused on using the traditionally cultivated medicinal plants and wild plant species was initiated.

The Balinese believe that all diseases can be cured with the help of nature. Like the Javanese and other cultures, the Balinese also believe that God has provided cures for any diseases. Therefore, it is part of the Balinese culture to look for medicinal plants to solve health problems. As in many other regions in Indonesia, herbal remedies remain Bali's cornerstone of treatment for most diseases. Though synthetic medical products have become common since the early 20th century, the use of folk remedies is still high, especially in Java and Bali.

The utilization of plants for preparing herbal drinks in Bali is an old local tradition. One of the most common herbal drinks is *Loloh*, which is generally prepared as decoctions of plants and is commonly used to treat a variety of ailments. *Loloh* is a herbal drink produced and consumed exclusively

in Bali to prevent and treat different ailments. The plant materials may consist of leaves, fruits, sap, rhizomes, bark, stem, flowers, and seeds from a single or multiple species, collected from the surrounding forests.

Sujarwo et al. (2015) recorded 51 plant species used for the preparation of *Loloh*. They belong to 32 families (the *Zingiberaceae* being the most represented family) and 48 genera (Table 4.1). Thirty types of ailments are treated using the species of plants recorded in the study; the most cited ailment is heartburn. In a few cases, informants indicated different uses of these plants (e.g., food uses). The plant parts, which are harvested to prepare the traditional herbal drinks, are listed in Table 4.1 with leaves being the most frequently used part. The result of the study suggests that aerial plant parts (87%) are preferred to underground parts (13%); this may be due to the easier accessibility in harvesting the plant sources (Cunningham, 2001).

Herbal drinks are generally prepared using simple procedures. The principal modes of preparation are decoction (70%) or juice (21%), while in some cases, liquids contained in the plants are consumed directly (5%). In some cases, the plants have additional uses, for example, external use as a paste (4%). The juice is extracted from plant parts using traditional simple techniques, which involve grinding with a flat stone or pestle; the juice is then filtered by twisting the plant materials in a clean cloth. Decoctions are prepared by simply boiling the mixture of plant parts in water on a traditional stove. Fresh plants are often used. Drying the plant materials in direct sunlight is generally avoided as the local people believe that such treatment may damage the 'good ingredients' (the medicinal properties) contained. Although most preparations were obtained from a single plant species, mixtures with secondary species were also practiced in some cases. Some of these secondary species are not

reported here, while others are listed as they constitute the main ingredient of another preparation. For example, a decoction of *Piper betle* leaves and *Zingiber montanum* rhizomes is prepared for sore throat. A decoction of the bark of *Alstonia scholaris* and bark of *Erythrina hypaphorus* is used for diarrhea, heartburn, and to stimulate appetite, while a decoction of *Spondias pinnata* and *Alpinia galanga* leaves is used for heartburn. In some cases, the Balinese also add palm sugar, coconut water, or salt to improve the acceptability and palatability of *Loloh* drinks.

All most cited plants have many documented pharmacological activities and are well-studied for their chemical profiles. For example, in *Alstonia scholaris*, more than 400 different compounds have been isolated and it is very rich in alkaloids, and also contains steroids, flavonoids, and triterpenoids (Baliga, 2012). *Blumea balsamifera* contains more than 100 known compounds (Pang et al., 2014). *Alstonia scholaris*, *Blumea balsamifera*, *Cinnamomum burmanni*, and *Piper betle* all have many ethnobotanical uses in several folk pharmacopeias (e.g., Meena et al., 2011; Al-Dhubiab, 2012; Pang et al., 2014). Some plants have documented ethnomedicinal uses in several tropical regions but are understudied for their potential in pharmacological activity. Another example is *Lygodium circinatum*, which is used to neutralize snake venom, treat insect bites, eye infections, and wounds (Puri, 1970; Baltrushes, 2006; Samuel et al., 2010), has only been studied for moderate antioxidant activity and an □-glucosidase inhibitory activity (oleanolic acid) (Lai & Lim, 2011). *Pneumatopteris callosa* has never been studied for pharmacological activities or its phytochemistry.

Living in the center of one of the most diverse tropical rainforest regions of Malesia, the Balinese people have a deep knowledge and respect for their environment. They are superb in identifying, harvesting, processing, and using the

sources of plant materials for their traditional herbal drinks. The study conducted by Sujarwo et al. (2015) contributed to increasing the knowledge on plants used for preparing herbal drinks and substantiated other previous studies documenting a general rich ethnomedicinal knowledge (Tengah et al., 1995; Astuti et al., 2000; Leurs, 2010). This knowledge, through continuous practice, has been carefully preserved through generations by Balinese shamans or *balian usada* and religious leaders (Hobart, 1990). Unfortunately, the young generations of Balinese (particularly those who live in the cities and have a higher education) nowadays prefer modern western medicine. Nevertheless, the people (including younger generations) who live in villages or rural areas still prefer herbal medicines, including *Loloh*, as they are relatively cheaper, easily available, and can be used directly (i.e., self-treatment). Young people learn how to prepare *Loloh* from family members, even though their mothers are mostly the ones who prepare *Loloh* for them. In some of the Bali traditional villages (e.g., Sembiran and Songan), the migration of younger generations in search of jobs, the increased globalization, and industrialization of agriculture potentially affect the persistence of traditional knowledge of plants. On the other hand, in the villages of Panglipuran and Bayung Gede, traditional knowledge of plants provides income for some family where *Loloh* is one of significant commercial value. In *Loloh*, leaves constitute the most important ingredient. Leaves are easily accessible and there is a belief that leaves may possess a strong medicinal value (Singh & Lal, 2008; Poonam & Singh, 2009). This belief is recorded in ancient medicinal scripts, such as Ayurveda in India (Sharma, 2008) and *Taru Pramana* in Bali (Worsley, 1972; Hobart, 1990). With some preparations, such as decoctions or juices, people also mix palm sugar (obtained from cooked sap harvested from the inflorescences of *Arenga*

pinnata or *Cocos nucifera*), salt, and coconut water in order to enhance their acceptability and also the properties of the herbal drinks. The *aren* (*Arenga pinnata*) and coconut (*Cocos nucifera*) are two species of palms that are both abundant in Bali and play important roles in the Balinese culture. Besides the use of *aren* as a source of sugar (known in Balinese as *gula aren* or *gula Jawa*), the plant is also used to produce liquor (obtained from the fermentation of sap) known in Balinese as *tuak* (which is also consumed by the Javanese, Sundanese, and many other tribes in Indonesia, including the Malay and Batak). *Aren* is also harvested for its trunk as an important source of starch (the Balinese, Javanese, and Sundanese sago; while the eastern Indonesians sago is mainly harvested from a different plant species, *Metroxylon sagu*). Moreover, the *sada*, which is the main mid-rib of the leaves of *aren*, is used for making brooms with claimed magical powers used in demoniac expulsion (Belo, 1949; Koentjaraningrat, 1985).

The role of *Zingiberaceae* as the most represented family in the ingredients of Balinese herbal drinks is not surprising since the family is well known as the most important source of spices in South and Southeast Asia (Seidemann, 2005; Xizhen et al., 2005; Khare, 2007; Remadevi et al., 2007). The medicinal uses of various species of this family in traditional Balinese herbal drinks are also mentioned and described in full detail in Balinese ancient scriptures of medicine like the *Lontar Usada* Bali and *Taru Pramana* (Worsley, 1972; Hobart, 1990; Tengah et al., 1995). The *Acanthaceae* and *Moraceae* are also well-represented. A large number of informants cited *Artocarpus heterophyllus* (even though the highest number of citations is for its use as food), whereas *Morus alba* is less commonly mentioned. *Morus alba* is an exotic species native to China and was probably introduced to Bali by the Dutch during the colonial time, potentially explain-

ing the reason why the Balinese are less familiar with this species. *Artocarpus heterophyllus* (both roots and leaves), as other *Artocarpus* species, is known to have medicinal uses in treating diarrhea (Jagtap and Bapat, 2010). This species has been extensively studied and has several demonstrated pharmacological activities (e.g., antimicrobial, antidiabetic, anti-inflammatory) (Jagtap and Bapat, 2010). The Apocynaceae is an important family of flowering plants among the medicinal species used in Asia and the Pacific (Wiart, 2006a, 2006b). In this family, the genus *Alstonia* is especially important for medicinal purposes (Wiart, 2006a). *Alstonia scholaris* is an evergreen tree with a widespread distribution from India, Sri Lanka, mainland Southeast Asia through the Pacific region, including Australia (Baliga, 2012). The plant has various ethnobotanical uses (Meena et al., 2011). The species has a validated activity against *Plasmodium berghei* supporting its use to treat malaria. All the other uses of *Alstonia scholaris* that have been cited by our informants also have been validated by pharmacological studies. *Blumea balsamifera* (Asteraceae) is also cited by a large number of local Balinese. This shrub is largely spread from India to Papua New Guinea (Pornpongrungrueng et al., 2007). The species has many activities, including antimicrobial, anti-inflammatory, hepatoprotection, and others. These activities do not explain the entire current uses for *Loloh*, therefore this species could probably have other pharmacological activities that are still unknown. The medicinal uses of *kayu manis* (*Cinnamomum burmanni*) in Indonesia is legendary. This species is widely commercialized and is known as 'Indonesian Cassia' or 'Batavia Cassia' (Hasanah et al., 2004; Al-Dhubiab, 2012). This species can be found in Southeast Asia and is cultivated in Indonesia (Al-Dhubiab, 2012). The Balinese use this species for various purposes, from cooking ingredient to medicine as part of a traditional knowledge

that they share with numerous tribes in Indonesia, from Sumatra to New Guinea. However, the use of *Cinnamomum burmanni* is apparently of Austronesian origin and was spread to the realm of Melanesia through contact back in ancient times during the Austronesian epical sails to the Pacific and Madagascar, presumably between 1000 BC and 400 BC (Pearce and Pearce, 2010). The Piperaceae is a family consisting of 10 genera with about 2,000 species, of which 30 species in Asia and the Pacific are used medicinally (Wiart, 2006a). *Piper betle* is a vine widely used throughout South Asia and Indonesia (Kumar et al., 2010). The plant has many pharmacological activities. *Piper betle* resides in the heart of the Balinese culture, and it is incorporated in various practices and uses from wedding ceremonies to medicine ingredients. Combined with the areca nut (*Areca catechu*) and other ingredients, *Piper betle* is used in one of the most important practices that characterize the Austronesian civilization (especially the West Central Austronesia) known as the tradition of *makan pinang sirih*. Several plants cited are poorly investigated for their pharmacological activity or chemical profiles. Considering that many other plants instead have already been tested and proved to be useful for many diseases and health problems, we believe that these understudied plants could also have interesting applications in pharmacology.

As for any medicinal plants, people should remain cautious while consuming plants due to the potential adverse effects. For example, unripened *Arenga pinnata* fruits are considered toxic due to a high content of calcium oxalate in the fruit peel (Lim, 2012). The ethanolic extract of *Azadirachta indica* stem bark may not be completely safe for internal use [see Ashafa et al. (2012) for more details]. *Lablab purpureus* seeds are edible if boiled and processed, otherwise, they are toxic (NC State University, 2014). Some toxic effects were

also described for *Sauropus androgynus* and *Sida rhombifolia* (Yu et al., 2007; Ouédraogo et al., 2013). Several plants are gathered preferably during the rainy season from November to April. This suggests that the Balinese are aware of the best timing for collecting the plant parts, and this is supported by several studies that have demonstrated differences in the concentration of active phytochemical constituents over the seasons. The Balinese are very respectful with regard to sustainable use of natural resources and they generally leave some parts for future regrowth and sprouting. Many species (such as *Alstonia scholaris*, *Andrographis paniculata*, *Andrographis indica*, *Blumea balsamifera*, *Cinnamomum burmanni*, *Cyclea barbata*, *Hibiscus tilliaceus*, *Orthosiphon aristatus*, *Piper betle*, *Spondias pinnata*), are conserved by Balian usada or the religious leaders and farmers because these species are largely consumed. Other conservation strategies should be fostered for some species, at a larger scale, to maintain their sustainable use. The following account presents the detailed description of ethnomedicine of several important species:

Ethnomedicine of Spondias pinnata

Sujarwo and Keim (2021) re-evaluated the previous work on the usage of *Spondias pinnata* in Bali (known locally as *cemcem* or *kecemcem*) which was concentrated more on the bioscience side of *cemcem* (Wrasiati et al., 2014). The following account provides more analyses and expansion of more ethnobotanical and ethno-bioprospecting perspectives by incorporating and following the model of previous work by Sujarwo et al. (2017). Leaves were selected to be the main source of materials for analysis as they were more commonly used in traditional medicine (Sujarwo et al., 2015). The leaf of *Spondias pinnata* was considered an integral part of the Balinese ethnobotanical knowledge and used in the making

of herbal-medicinal beverage to treat heartburn, urolithiasis, diabetes, and to improve body health (Sujarwo et al., 2015). Leaves could be consumed fresh as vegetables or boiled first to make a kind of traditional medicinal drink or *Loloh*. The bioprospecting side of the study conducted by Sujarwo & Keim (2019) (as the foundation of the ethno-bioprospecting value) was to evaluate the antioxidant activities and phenolic content of leaf of *Spondias pinnata* found in Bali.

According to Sujarwo et al. (2015), among 50 informants interviewed only seven of them, all male, mentioned the medicinal uses of *cemcem*. Indeed, among the 13 surveyed villages, the uses came only from two villages that were, Penglipuran and Tenganan, where the plant grew, and often appeared as a home garden plant. In fact, the plant could be found in lowland areas up to 500 m above sea level. However, the ethnobotanical values have only been obtained from the two villages. The informants also declared that local people consumed herbal drinks made from *cemcem* leaves at least once a week. According to Sujarwo and Caneva (2016), *cemcem* availability index (the availability of the plant) was rare to medium, and its use value (the number of uses) and relative importance (the local importance of species) were 0.14 and 0.67, respectively. In addition to some ethnobotanical indices, the taste score appreciation obtained from the local inhabitants was fair.

In the *Usada Bali* (the book of Balinese Traditional Medicine), *Spondias pinnata* leaves have been described as the remedy to cure various ailments and diseases (Tengah et al., 1995; Sujarwo et al., 2015). In spite of lack of direct evidence, *Spondias pinnata* leaves can prevent or cure heartburn, urolithiasis, and diabetes (Sujarwo et al., 2021). The antidiabetic effect might be enhanced by using the traditional method of serving the *cemcem* leaves as an herbal drink intended to treat high blood sugar levels. This herbal drink

is a kind of juice, which has been traditionally used by the Balinese for thousands of years. It is believed that *Spondias pinnata* leaves have been used since the 11th century in the Indonesian island of Bali (Pringle, 2004; Sujarwo et al., 2021).

People living in the traditional villages in Bali have been using antioxidants and polyphenols as a part of their traditional medicine for centuries. Sujarwo et al. (2017) indicated that *Spondias pinnata* possesses strong antioxidant activities based on ABTS•+ and DPPH assays. It is also concluded that 100% methanolic extracts of *Spondias pinnata* leaves contain large amounts of phenolic compounds mainly responsible for free radical scavenging activities. Further study is essential in order to better understand the therapeutic values of *Spondias pinnata* leaves and its role in the prevention and treatment of ailments and chronic diseases such diabetes, heartburn, and urolithiasis.

The most recent study on the ethnobotany of this species with account of Bali included is by Sujarwo and Keim (2020), in which the bioculture of this species is greatly discussed.

Ethnomedicine of Azadirachta indica

Although there have been few populations of neem trees found in Bali, still neem is one of important plants for Balinese in medicinal purposes. It could be seen that *Balian usada*, an indigenous medical practitioner who is knowledgeable on plant uses, conserved the species by leaving some parts for future re-growth and sprouting. Despite still following the practice written in Ayurveda, in Bali only leaves are harvested for their medicinal and insecticidal purposes (Förster & Moser, 2000; Paterson, 2009). Furthermore, neem is only fruiting once a year; thus the fruits and seeds are not always affordable. Therefore, harvesting fruits are regarded less efficient by the Balinese and thus abandoned despite

the fact that there is a great possibility that they may know that the seeds of neem have higher medicinal contents than the leaves through reading the Ayurveda (Tengah et al., 1995; Nala, 1996). Leaves are proven to be a widely used plant parts (Martin, 1995; Cotton, 1996; Balangcod & Balangcod, 2011), and such result is confirmed for Bali (Sujarwo et al., 2015). Sujarwo et al. (2016) showed that the differences of traditional use of neem between Bali and the Indian subcontinent is believed to the fact that neem is an introduced plant to Bali and the Balinese have their own medicinal system rooted in the already established Austronesian civilization long before the contact with the Aryan Sanskrit speaking civilization. Thus, the use of the exported neem into the Balinese system of medicine would be regarded as 'implementing thing of an uncertain result'. Consequently, the Balinese –as other people in the world when faced with something new– would naturally implement the most widely used plant parts that regarded most safe, i.e. leaves.

B. Edible Local Plants

Sujarwo et al. (2016) recorded 86 ethnobotanical food plants belonging to 41 families and 68 genera. The families with relatively high number of species are *Fabaceae* (6), *Rosaceae* (6), *Euphorbiaceae* (5), *Arecaceae* (5), *Myrtaceae* (5), *Moraceae* (4), and *Araceae* (4). The genera containing the highest number of species are *Rubus* (6), followed by *Syzygium* (4) and *Dioscorea* (3). The dominant life forms are trees (39%), followed by climbers (21%), perennial herbs (20%), shrubs (19%), and woody climbers (1%). The most frequently used parts are fruits, leaves, tuberous roots, seeds, and young leaves. People collect most plants throughout the year. Most uses are specific to a particular plant parts (such as fruit, leaf, tuberous root, seed, and young leaf), although in a few cases a single part of the plant has multiple uses,

such as the bark of *Cinnamomum burmanni* is used as a spice or as an ingredient in herbal drinks. For about 28% of the species, more than one parts of the plant are used. For example, young fruits and seeds of *Artocarpus heterophyllus* (breadfruit) are used as a vegetable, while leaves are used in an herbal drink. The inner stems of *Arenga pinnata* are used as a staple food, while the roots are used in an herbal drinks, and its fruit is eaten fresh. The fruit and leaves of *Moringa oleifera*, *Averrhoa bilimbi*, *Averrhoa carambola*, and *Cucurbita moschata* are consumed as vegetables. The young leaves of *Zingiber purpureum* are used as a vegetable and the tuberous roots as a condiment. The fruits of *Tamarindus indica* and *Solanum nigrum* are eaten fresh, and the leaves are consumed as vegetable. Overall, fruit (35%) and vegetable (34%) are the categories that have most uses, followed by the categories of additional use (13%) and staple food (9%). Fruits are often eaten fresh, while green leafy vegetative parts (e.g., leaves, young leaves, tip leaves, and stems) are usually boiled, cooked, or added to soups, and less commonly are used fresh in salads. All these parts are used as ingredients for *Lawar* (mixed vegetables), which is very popular among the Balinese.

Edible wild and semi-wild plants play an important role in providing the inhabitants of Bali with various essential nutrients, such as vitamins and minerals needed to maintain health and improve immunity to diseases (Sujarwo et al., 2016). For example, a well-known traditional Balinese dish is a *jukut undis* soup with red rice, which is the seeds of *Cajanus cajan*, reported to have low cholesterol, high dietary fiber, protein, carbohydrate, minerals, and thiamine (USDA, 2014).

In addition to edible use, Sujarwo et al. (2016) showed that 16.28% of plants recorded (14 species) have additional uses. Such species are common in rural areas and important

to local communities. They not only balance the nutritional value of starchy diets (compensating for the lack of some vitamins, proteins and minerals), but may also provide pharmacologically active compounds. These multiple uses prove the importance of these plants for subsistence and as a part of the local cultural heritage (Shrestha and Dhillion, 2006; Ju et al., 2013).

Wild and semi-wild edible plants can provide resources for future development of new health foods. As living standards rise, there is an increasing global demand for healthy and safe food (Zou et al., 2010). Compared to cultivated vegetables, wild and semi-wild food plants require less maintenance, are not affected by pesticide pollution, and are a rich source of micronutrients (Ju et al., 2013). Six species have cultural significance in a religious rite named *banten*, during which specific plants are used as ornamentation. They are *Colocasia esculenta*, *Arenga pinnata*, *Borassus flabelifer*, *Dioscorea hispida*, *Aleurites moluccanus*, and *Pangium edule* (Sujarwo et al., 2016). The rite plays an important role in the daily life of the people of Bali, and it is said that the *banten* is not only able to purify the soul, but it is also believed that it protects and preserves food supplies. The Balinese use the *banten* rite to pray for happiness, prosperity, a good harvest, and good fortune.

Aside from having importance as a food source, the species recorded provide the inhabitants of rural areas with the possibility of limited cash opportunities that supplement their household income (Sujarwo et al., 2016). *Colocasia esculenta*, *Artocarpus heterophyllus*, *Piper betle*, and *Zingiber purpureum* are the most frequently mentioned vegetable. In Bali, the leaves of these four species are eaten as a vegetable. They are added to soups, stir-fried, or eaten together with other vegetables. Several studies have focused on a nutritional analysis of these plants and found that they con-

tained carbohydrates, protein, vitamin C, vitamin A, dietary fiber, low fatty acids, and mineral elements in quantities comparable with some common vegetables (Pradhan et al., 2013; USDA, 2014). Although local people do not use it as a medicine, *Artocarpus heterophyllus* is recorded as an ingredient in herbal drinks since ancient times. For instance, the leaves are used to treat diarrhea, and young fruits and seeds have commercial values with prices at the traditional market varied from 7000 IDR (Indonesian rupiah) to 10,000 IDR (ca. 1 USD = 14,500 IDR) per kilogram (fresh weight) from April to December.

Other preferred plants (mentioned by more than 50% of respondents in Sujarwo et al. 2016) include *Arenga pinnata*, *Dioscorea hispida*, *Cajanus cajan*, *Cinnamomum burmanni*, *Moringa oleifera*, *Psidium guajava*, and *Diplazium esculentum*. All these plants are collected by local people mainly in forest areas and sold at traditional markets, providing local people on low incomes with a chance to increase their income. Another renowned edible fruit, known as *gunggung*, which includes six species, i.e., *Rubus alpestris*, *Rubus calycinus*, *Rubus chrysophyllus*, *Rubus fraxinifolius*, *Rubus lineatus*, and *Rubus rosaefolius*. The fruits are collected mostly between November and April. When young they are sour but rich in vitamin C and minerals and low in fat (USDA, 2014). One local industry already exploits the fruit of *Rubus rosaefolius* commercially. Sujarwo et al. (2016) found that taste and availability are the principal criteria for all types of edible plants, in agreement with other surveys (Dansi et al., 2008). However, taste itself is not enough to build a reliable list of priorities for future conservation, domestication, and exploitation. Furthermore, detailed nutritional analyses and phytochemical studies should be carried out to comprehensively evaluate food and nutraceutical values of the 'most preferred' plants, and provide scientific and critical information (Ju et al., 2013).

It is generally believed that local people are more likely to support and participate in conservation initiatives if they benefit directly from such efforts (Acharya & Acharya, 2010; Ju et al., 2013). If managed sustainably, these plants can be a good source of income for rural communities. Some species are becoming rare on the island of Bali, although there were rich resources 20 years ago (Astuti et al., 2000; Leurs, 2010). Land use changes were observed and identified as causes of the decline of *Amorphophallus campanulatus*, *Antidesma bunius*, *Arenga pinnata*, *Artocarpus elasticus*, *Averrhoa bilimbi*, *Borassus flabellifer*, *Paederia scandens*, *Sandoricum koetjape*, *Syzygium polycephalum*, and because few people in this area are aware of sustainable land use management, conservation of these plants should be undertaken both in situ and ex situ.

Of the botanical species listed in Sujarwo et al. (2016), 10 species are not reported in Kunkel's checklist on edible plants of the world (Kunkel, 1984), hence these species should be the subject of further in-depth investigations. Moreover, a certain number of plants have not been thoroughly studied for their nutritive value or from a pharmacobotanical point of view. Among these, we can cite *Dendrocnide stimulans*, *Diplazium repandum*, *Elsholtzia elata*, *Heliconia wagneriana*, *Musa brachycarpa*, *Nicolaia speciosa*, *Pneumatopteris callosa*, *Rubus lineatus*, *Schleichera oleosa*, and *Syzygium polycephalum*. In Sujarwo et al. (2016), some fruits are very interesting in the case that they contain powerful antioxidant compounds, e.g., xanthones in *Garcinia dulcis* and *Garcinia parvifolia* (Haruenkit et al., 2007). Other plants have additional properties, e.g., antidiabetic in *Cajanus cajan* (Gunjan et al., 2011), anti-inflammatory in *Ipomoea pes-caprae* (Pongprayoon et al., 1991), and antimutagen in *Syzygium cumini* (Saxena et al., 2013).

Caution should be taken regarding the consumption of some species containing toxic compounds, e.g., *Gynura* spp. (*Asteraceae*, group *Senecioneae*) for the presence of toxic pyrrolizidine alkaloids (Matheson & Robins, 1992), *Solanum nigrum* which contains toxic alkaloids, like solanin, *Euphorbiaceae* for caustic latex, and some ferns (*Blechnum orientale* and *Diplazium spp*.) which contain anti-vitamins. According to Kunkel (1984) some plant parts should be ingested in small amounts (e.g., the tuberous roots of *Coleus parviflorus*, and the nuts of *Aleurites moluccanus*, perhaps better roasted). Other warnings regard the tuberous roots of *Dioscorea hispida*, which are toxic unless soaked in saltwater. *Pangium edule* is considered a poisonous species, although its seeds are said to be eaten after prolonged soaking or being buried for a long period (Kunkel, 1984).

It has been estimated that, globally, there are around 216,000 wild relatives of crop species and among these only 1,200 are primary and secondary relatives, although these estimations rely largely on European and Mediterranean flora, and many other parts of the world have yet to be explored (Maxted & Kell, 2009; Uprety et al., 2012). Wild and semi-wild crop relatives, which are species that are closely related to crops and include crop progenitors, may provide genes with a higher resistance to adverse circumstances which could prove particularly important in response to global climate change (Hajjar & Hodgkin, 2007; Maxted & Kell, 2009; Uprety et al., 2012; Ju et al., 2013). They are also of great significance in maintaining the productivity and stability of traditional agro-ecosystems (Harlan, 1965; Meilleur & Hodgkin, 2004; Ju et al., 2013). Their conservation will ensure that genetic resources are preserved so as to enhance food security (Pandey et al., 2008; Ford-Lloyd et al., 2011; Uprety et al., 2012; Ju et al., 2013). Biodiversity and indigenous knowledge inventories are the starting point

for both in situ and ex situ conservation campaigns which can provide critical baseline data for the assessment and monitoring of biodiversity (Blasi et al., 2005; Heywood et al., 2007; Ju et al., 2013).

Some species recorded in Sujarwo et al. (2016) study can be identified as wild and semi-wild relatives of vegetable crops (e.g., *Blechnum*, *Coccinia*, *Diplazium*, *Gynura*, *Ipomoea*, *Momordica*, *Piper*, and *Sauropus*), fruit crops (e.g., *Acanthus*, *Antidesma*, *Areca*, *Borassus*, *Elaeocarpus*, *Flacourtia*, *Rubus*, *Schleichera*, and *Syzygium*), and spice and staple food crops (e.g., *Alocasia*, *Amomum*, *Arenga*, *Cinnamomum*, *Coleus*, *Colocasia*, *Dioscorea*, and *Nicolaia*). Due to their advantageous traits such as high adaptability and longevity, resistance to disease, and tolerance to drought and flood, they can constitute a genetic resource for improved cultivation techniques.

Balinese home gardens

The production of fruit and vegetables in home gardens has a long tradition in Bali (Astuti et al., 2000). To the best of our knowledge there are no ethnobotanical studies of cultivated plants in Balinese home gardens before Sujarwo and Caneva (2015). They recorded 36 species belonging to 20 families and 29 genera. The most common families are *Zingiberaceae* (6 species), followed by *Poaceae* (5 species), *Fabaceae* (4 species), *Anacardiaceae*, *Cucurbitaceae*, *Asteraceae*, and *Euphorbiaceae* (2 species each). The most frequently used parts are leaves, fruits, tuberous roots, young leaves, and young shoots. Most plants are collected throughout the year. In a few cases a single plant part has multiple uses, e.g., the juice or the uncooked ripe fruit of *Cyphomandra betacea* is used by locals to treat aphthous stomatitis and hypertension.

Sujarwo and Caneva (2015) show that local home gardens are important reservoirs of plant species cultivated for vegetables (46%), medicines (2%), edible fruits (20%), spices (9%), and edible seeds (2%). However, 22.22% of all recorded plants have more than one use category. The multiple uses demonstrate the importance of these plants for subsistence and as a part of local cultural heritage (Addis et al., 2005; Shrestha & Dhillion, 2006; Ju et al., 2013; Sujarwo et al., 2015). Even though almost 2000 species of plants occur in the island of Bali, we only obtained 36 cultivated ethnobotanical plants. These plants are known as crops, but their uses are very traditional, and only exist in a particular area. Sujarwo and Caneva (2015) emphasizes the relationship between cultivated plants and traditional uses, for example everyone should know banana (*Musa paradisiaca*), but such local knowledge that cooked core stems of banana can be added to vegetable soups, only exists in Bali.

The home gardens are located close to the houses, and composed mainly of fruit plants. The gardens provide quick and easy access to foodstuffs, such as *Garcinia mangostana*, *Mangifera caesia*, *Mangifera odorata*, *Morus australis*, *Persea americana*, and *Punica granatum*, for household consumption. According to Sujarwo and Caneva (2015), the top-five cultivated plants cited were *Manihot esculenta*, followed by *Musa parasidiaca*, *Blumea balsamifera*, *Ipomoea batatas*, and *Carica papaya*. These species, with the exception of *Blumea balsamifera*, which is used to treat diarrhea, fever, heartburn, and constipation, are the main food species consumed. The leaf of *Manihot esculenta*, which is the most commonly used of all plant species, and is known by all age groups of the community (Sujarwo et al., 2014), is particularly appreciated because it is easy to grow and can be used in a wide variety

of dishes. One of Bali's most famous traditional foods is *jukut ares* soups made from the core of the stems of the banana plant (*Musa parasidiaca*) (Sujarwo et al., 2016).

According to Sujarwo and Caneva (2015), among the cultivated plants recorded and categorized as local food crops, *Carica papaya*, *Luffa acutangula*, *Nephelium lappaceum*, *Phaseolus lunatus*, *Phaseolus vulgaris*, *Psophocarpus tetragonolobus*, and *Salacca zalacca* were identified as the most important market oriented crops. *Ipomoea batatas* and *Manihot esculenta* are both used as food crops and are very valuable cash crops. The most cited multipurpose species was *Luffa acutangula*, whose cooked leaves are added to vegetable soups, and whose seeds are boiled and eaten. Sujarwo and Caneva (2015) also documented certain neglected plant species, which were reported by fewer than three informants as grown in their home gardens, i.e., *Phaseolus lunatus*, *Phaseolus vulgaris* (whose cooked leaves and seeds are used in vegetable soups to treat heartburn), *Saccharum officinarum* (used to treat coughs), *Schizostachyum lima*, *Nephelium lappaceum*, *Cyphomandra betacea*, and *Curcuma zanthorrhiza* (known in Balinese as *temu agung*, whose root juice is also used to treat heartburn). Many plants found in Balinese home gardens are typical of home gardens throughout the Tropics, e.g., bananas, mango, avocado, papaya, *Citrus* spp., cassava, sweet potatoes, *Phaseolus* spp., gourd and sugar cane (Figueiredo et al., 1993; Jensen, 1993; De Clerck & Negreros-Castillo, 2000; Wezel & Bender, 2003; Sunwar et al., 2006; Mohan et al., 2007; Vlkova et al., 2011). *Salacca zalacca*, on the other hand, is a species of palm tree native to Java (Indonesia), and has been reported in Balinese home gardens. One of the more popular cultivars throughout the region is a cultivar Bali popularly known as *Salak Bali* (Govaerts & Dransfield, 2005).

The floristic regions of the 36 cultivated plants in Sujarwo and Caneva (2015) include Malesia (37.5%), India (21.43%), Indochina (12.5%), the Caribbean (8.93%), and the Andes (8.93%). The first reports of the introduction into Indonesia of plants native to India and Indochina appeared in an eighth century Javanese charter. This coincides with the introduction of Indian religious and cultural influences during the same period (Terra, 1954; Soemarwoto, 1987). The presence in Indonesia of plants native to Central and South America is first recorded in the sixteenth century (Simmonds, 1976). Home gardens probably originated 10,000 years ago or more, when hunter gatherers discarded domestic refuse containing seeds and other plant matters in the vicinity of their camps and then tended and protected the plants that appeared (Hutterer, 1984; Soemarwoto, 1987; Casas et al., 1996).

C. Building Materials

The buildings of the local Balinese have been studied architecturally by researchers such as Aranha (1991), Budihardjo (1985), and Lansing (1983). These previous studies mostly concentrated on the architectural and artistic aspects of Balinese buildings and the comparison with 'fellow Hindu' buildings in Nepal. There is no detailed information regarding the botany of the plant species used and how the Balinese use them. Therefore, Sujarwo and Keim (2017) described the plant species related to traditional Balinese knowledge of building materials, to discover the most valued plant species according to their uses and origin, and to achieve a better understanding of species diversity within the areas under investigation and the sustainability of using plant-based building materials. The results of their study indicated that 78 species of plants from 63 genera and 34 families were regarded as being useful as building materials. Three

families were considered particularly important sources of building materials by the local inhabitants; *Poaceae* (8 species), *Meliaceae* (7 species), and *Malvaceae* (5 species). The plant part used most often was the stem (88%), and the main use categories reported for building materials were houses (58%), where a total of 63 plant species were used in the construction of houses and their roofs, of which eight belong to the grass family (*Poaceae*), such as bamboos and *Imperata cylindrica*. Other use categories were religious uses (Balinese Hindu temples; 35% or 37 species), stables (5% or 6 species), and barns (2% or 2 species) (Table 4.2). Thirty-eight percent of recorded plant species appeared in more than one use category, such as the stem of *aren* or 'sugar palm' (*Arenga pinnata*), which was used for various purposes like religious buildings (Balinese Hindu temple), houses, and stables (cowshed). As a building material, the stem of *Arenga pinnata* is renowned for its strength and durability (Dransfield et al., 2008; Keim et al., 2012; Killmann et al., 1989; Mogea, 1991; Mogea et al., 1991; Uhl & Dransfield, 1987). It is recorded as being one of the most important building materials in Austronesian traditional houses (Fox, 2006).

Sujarwo and Keim (2017) stated that other plant material used in temple roofs were leaves from *Cocos nucifera* and *Imperata cylindrica*. However, the informants preferred fibers harvested from *Arenga pinnata* as the former plant's fibers were regarded as more durable than those of *Imperata cylindrica*. This was apparently due to the physical nature of the fibers, which are hard, durable, and water-resistant as previously discussed. A rope made from the black fibers of sugar palm was also used in the construction of traditional buildings. Temporary structures (such as cowsheds, pigpens, and barns) were often built using nearby plant species, as long as they were abundant, easy to use, and not regarded

as a sacred plant by local inhabitants. The main criterion in choosing a particular plant species as the source of residential building material was the local availability of the species. In many cases, although building sizes had become greatly reduced, the demand for plant-based building materials was, surprisingly, increasing (Badan Pusat Statistik, 2020).

Nowadays most Balinese have replaced black fibers from *Arenga pinnata* (i.e., *ijuk*) with metallic coated sheet steel, and walls originally made using plant-based materials are now made with bricks. This is positive in terms of the solidity of the wall; however, the replacement of *ijuk* with metal sheets can be seen as unfortunate, since a continuous use of *ijuk* would mean sustainable cultivation of *Arenga pinnata*, because the *ijuk* can be harvested throughout the year when the plant has reached maturity and will not kill the plant (Keim et al., 2012). In other words, this form of replacement was regarded as unfavorable for the conservation of *Arenga pinnata*.

In terms of *Arenga pinnata*, the species is also harvested and used by southern Indians, but it has long been suggested that the practices has been introduced by the Austronesians, who traveled there. There is a long history of trade between Malay Archipelago and southern India. The diversity of uses of *Arenga pinnata* in India is far less than in Austronesia. Rheede tot Drakenstein (1686) reported this in his Hortus Malabaricus, where the information regarding the use of *Arenga pinnata* in Malabar, India was reported. Compare to the use of the species by the Moluccans in Rumphius' Herbarium Amboinense (Rumphius, 1741), the use of the species in India is far less diverse. There is also a possibility that *Arenga pinnata* was introduced by Austronesians in ancient times from the Malay Archipelago to India. This is supported by the fact that there has been no report of wild *Arenga pinnata* in India.

Sujarwo and Keim (2017) noted that several species were identified by their interviewees as increasingly rare in Bali. One such species was the highly prized *cendana* or sandalwood (*Santalum album*). Present across a wide area from India to the Malesian region, including Bali, it used to be quite abundant in Bali, especially in hinterland areas (including the village of Trunyan, for example), at least until the mid-20th century (Rensch, 1930). But since then, the situation has changed dramatically (Sujarwo, 2013). Further analysis carried out during this study also supports the rarity of *Santalum album*, which is now exceptionally uncommon in Bali even in a cultivated state. Since at least the 1990s, various species have been introduced to replace *Santalum album*, and at the same time, efforts have been made to protect the species in its natural habitat. *Santalum album* has long been an integral part of Balinese culture, and in some ways it has itself become 'Balinese'. This is something that no other introduced species can replace and is therefore an important reason to encourage conservation of the species.

Despite the availability of such alternative species, the Balinese today admit that buildings are made differently now than they were in the time of their predecessors. In fact, the majority of modern Balinese admit that they no longer know exactly how to build traditional buildings like those of their ancestors.

Table 4.2 Plant Used for Building Materials in Bali

Plant families & species (life form)	**Vernacular names**	**Parts used & building type**	**Floristic region**
Anacardiaceae			
Mangifera caesia Jack (**Tree**)	Wani	Stem: House	Malesian

Plant families & species (life form)	Vernacular names	Parts used & building type	Floristic region
Mangifera indica L. (**Tree**)	Mangga, poh	Stem: Religious Use [Balinese Hindu temple], House	Indian
Mangifera odorata Griff. (**Tree**)	Mangga pakel	Stem: Religious Use [Balinese Hindu temple], House	Indochinese, Malesian
Annonaceae			
Cananga odorata (Lam.) Hook.f. & Thomson (**Tree**)	Sandat	Stem: Religious Use [Balinese Hindu temple], House	Malesian
Apocynaceae			
Plumeria rubra L. (**Tree**)	Jepun	Stem: Religious Use [Balinese Hindu temple]	Andean, Caribbean
Arecaceae			
Areca catechu L. (**Tree**)	Pinang	Stem: House	Malesian
Arenga pinnata (Wurmb) Merr. (**Tree**)	Jaka	Stem: Religious Use [Balinese Hindu temple], House, Stable [Cowshed]; Black Sugar-Palm Fibers: House	Indian, Malesian
Calamus javensis Blume (**Climber**)	Rotan	Stem: Cane is used for string.	Malesian
Cocos nucifera L. (**Tree**)	Kelapa	Stem: House; Leaves: House	Fijian, Malesian

Plant families & species (life form)	Vernacular names	Parts used & building type	Floristic region
Bignoniaceae			
Mansoa alliacea (Lam.) A.H.Gentry (**Climber**)	Kesuna	Stem: Religious Use [Balinese Hindu temple]	Andean
Radermachera gigantea (Blume) Miq. (**Tree**)	Pedanten, kedanten	Stem: Religious Use [Balinese Hindu temple], House	Indochinese, Indian, Malesian
Boraginaceae			
Cordia myxa L. (**Shrub**)	Kendal	Stem: House	Indian
Ehretia javanica Blume (**Tree**)	Blebu	Stem: Religious Use [Balinese Hindu temple], House	Malesian
Cannabaceae			
Trema orientalis (L.) Blume (**Tree**)	Lenggung	Stem: House	Indochinese, Indian, Malesian
Casuarinaceae			
Casuarina junghuhniana Miq. (**Tree**)	Cemara geseng	Stem: Religious Use [Balinese Hindu temple], House	Malesian
Chrysobalanaceae			
Maranthes corymbosa Blume (**Tree**)	Kayu buluh	Stem: House	Malesian

Plant families & species (life form)	Vernacular names	Parts used & building type	Floristic region
Clusiaceae			
Calophyllum soulattri Burm.f. (**Tree**)	Selatri	Stem: Religious Use [Balinese Hindu temple], House	Malesian
Garcinia celebica L. (**Tree**)	Pradah	Stem: House	Malesian
Garcinia parvifolia (Miq.) Miq. (**Tree**)	Badung	Stem: Religious Use [Balinese Hindu temple], House	Malesian
Combretaceae			
Terminalia catappa L. (**Tree**)	Ketapang	Stem: House	Indian, Malesian
Terminalia microcarpa Decne. (**Tree**)	Kayu kunyit	Stem: House	Malesian, Northeastern Australian
Cyatheaceae			
Cyathea contaminans (Wall. ex Hook.) Copel. (**Tree**)	Paku tiang	Stem: House	Malesian
Elaeocarpaceae			
Elaeocarpus serratus L. (**Tree**)	Genitri	Stem: Religious Use [Balinese Hindu temple], House	Indian
Euphorbiaceae			
Aleurites moluccanus (L.) Willd. (**Tree**)	Tingkih	Stem: Stable [Cowshed, Pigpen]	Indochinese, Indian, Malesian

Plant families & species (life form)	Vernacular names	Parts used & building type	Floristic region
Icacinaceae			
Platea latifolia Blume (**Tree**)	Udu	Stem: House	Indochinese, Indian, Malesian
Lamiaceae			
Vitex trifolia L. (**Shrub**)	Lengedi	Stem: Religious Use [Balinese Hindu temple], House	Malesian, Madagascan, Sudano-Zambezian
Lauraceae			
Lindera polyantha Boerl. (**Tree**)	Kayu dis	Stem: House	Malesian
Persea americana Mill. (**Tree**)	Alpukat	Stem: House	Caribbean
Lecythidaceae			
Planchonia valida (Blume) Blume (**Tree**)	Kutat	Stem: Religious Use [Balinese Hindu temple], House	Indochinese, Malesian
Leguminosae			
Albizia chinensis (Osbeck) Merr. (**Tree**)	Belalu	Stem: House	Indian, Malesian
Albizia procera (Roxb.) Benth. (**Tree**)	Tingas, wangkal	Stem: Religious Use [Balinese Hindu temple], House	Indian, Malesian
Erythrina subumbrans (Hassk.) Merr. (**Tree**)	Dadap	Stem: House	Indochinese, Indian, Malesian

Plant families & species (life form)	Vernacular names	Parts used & building type	Floristic region
Falcataria moluccana (Miq.) Barneby & J.W.Grimes (**Tree**)	Sengon lokal	Stem: Religious Use [Balinese Hindu temple], House	Malesian
Lythraceae			
Lagerstroemia speciosa (L.) Pers. (**Tree**)	Kayu tangi	Stem: House	Indian, Malesian
Magnoliaceae			
Magnolia × *alba* (DC.) Figlar (**Tree**)	Base	Stem: Religious Use [Balinese Hindu temple], House	Indochinese, Malesian
Magnolia champaca (L.) Baill. ex Pierre (**Tree**)	Cempaka kuning	Stem: Religious Use [Balinese Hindu temple]	Indochinese, Indian, Malesian
Magnolia sumatrana var. *glauca* (Blume) Figlar & Noot. (**Tree**)	Kepelan	Stem: Religious Use [Balinese Hindu temple], House	Malesian
Michelia alba DC. (**Tree**)	Cempaka putih	Stem: Religious Use [Balinese Hindu temple]	Indochinese, Malesian
Malvaceae			
Hibiscus elatus Sw. (**Tree**)	Waru lot	Stem: Religious Use [Balinese Hindu temple], House	Caribbean
Hibiscus tiliaceus L. (**Tree**)	Waru	Stem: Religious Use [Balinese Hindu temple], House	Polynesian

Plant families & species (life form)	Vernacular names	Parts used & building type	Floristic region
Melochia umbellata (Houtt.) Stapf (**Shrub**)	Bentenu	Stem: Religious Use [Balinese Hindu temple], House	Indian, Malesian, Northeast Australian
Pterospermum javanicum Jungh. (**Tree**)	Bayur	Stem: Religious Use [Balinese Hindu temple], House	Indochinese, Malesian
Schoutenia ovata Korth. (**Tree**)	Kalikukun	Stem: Religious Use [Balinese Hindu temple], House	Indochinese, Malesian
Meliaceae			
Azadirachta indica A.Juss. (**Tree**)	Intaran, mimba	Stem: House	Indian
Dysoxylum cyrtobotryum Miq. (**Tree**)	Kwanitan	Stem: Religious Use [Balinese Hindu temple], House	Indochinese, Malesian
Dysoxylum parasiticum (Osbeck) Kosterm. (**Tree**)	Majagau	Stem: Religious Use [Balinese Hindu temple]	Malesian
Lansium parasiticum (Osbeck) K.C.Sahni & Bennet (**Tree**)	Ceruring, langsat	Stem: House	Malesian
Melia azedarach L. (**Tree**)	Jempinis, mindi	Stem: Religious Use [Balinese Hindu temple], House	Indochinese, Indian, Malesian, Northeastern Australian

Plant families & species (life form)	Vernacular names	Parts used & building type	Floristic region
Sandoricum koetjape (Burm.f.) Merr. (**Tree**)	Sentul	Stem: House, Stable [Cowshed, Pigpen]	Indochinese, Malesian
Toona sureni (Blume) Merr. (**Tree**)	Suren	Stem: Religious Use [Balinese Hindu temple], House	Indochinese, Malesian
Moraceae			
Artocarpus elasticus Reinw. ex Blume (**Tree**)	Te'ep	Stem: Religious Use [Balinese Hindu temple], House	Indochinese, Malesian
Artocarpus heterophyllus Lam. (**Tree**)	Nangka	Stem: Religious Use [Balinese Hindu temple]	Indian
Ficus variegata Blume (**Tree**)	Kayu babi	Stem: House	Fijian, Indian, Malesian, Northeast Australian
Streblus asper Lour. (**Tree**)	Pali	Stem: Religious Use [Balinese Hindu temple]	Indochinese, Indian, Malesian
Myrtaceae			
Eucalyptus alba Reinw. ex Blume (**Tree**)	Ampupu	Stem: House	Malesian, Northeast Australian
Syzygium cumini (L.) Skeels (**Tree**)	Juwet	Stem: House	Indian, Indochinese

Plant families & species (life form)	Vernacular names	Parts used & building type	Floristic region
Syzygium polycephalum (Miq.) Merr. & L.M.Perry (**Tree**)	Kaliasem	Stem: Religious Use [Balinese Hindu temple]	Malesian
Syzygium zollingerianum (Miq.) Amshoff (**Tree**)	Kayu batu	Stem: House	Malesian
Oleaceae			
Fraxinus griffithii C.B.Clarke (**Tree**)	Nangi, angih	Stem: House	Indochinese, Indian, Malesian
Phyllanthaceae			
Antidesma bunius (L.) Spreng. (**Tree**)	Buni	Stem: Religious Use [Balinese Hindu temple], Barn	Malesian, Northeast Australian
Baccaurea racemosa (Reinw. ex Blume) Müll. Arg. (**Tree**)	Kepundung	Stem: House	Malesian
Bischofia javanica Blume (**Tree**)	Gintungan	Stem: House, Stable [Cowshed, Pigpen]	Indian, Malesian, Polynesian
Poaceae			
Bambusa vulgaris Schrad. (**Tree**)	Bambu ampel	Culm: House	Indochinese
Dendrocalamus asper (Schult.) Backer (**Tree**)	Bambu petung	Culm: House	Malesian

Plant families & species (life form)	Vernacular names	Parts used & building type	Floristic region
Gigantochloa apus (Schult.) Kurz (**Tree**)	Bambu tali	Culm: Religious Use [Balinese Hindu temple], House	Malesian
Gigantochloa aya Widjaja & Astuti (**Tree**)	Bambu jajang aya	Culm: House	Malesian
Gigantochloa baliana Widjaja & Astuti (**Tree**)	Bambu bali	Culm: House	Malesian
Gigantochloa taluh Widjaja & Astuti (**Tree**)	Bambu jajang taluh	Culm: House	Malesian
Imperata cylindrica (L.) Raeusch. (**Grass**)	Alang-alang	Leaves: House	Eastern Asiatic, Madagascan, Malesian, Indian, Northeastern Australian, Sudano-Zambezian
Schizostachyum lima (Blanco) Merr. (**Tree**)	Bambu buluh	Culm: House	Malesian
Podocarpaceae			
Dacrycarpus imbricatus (Blume) de Laub. (**Tree**)	Cemara pandak	Stem: House	Indochinese, Malesian
Rubiaceae			

Plant families & species (life form)	Vernacular names	Parts used & building type	Floristic region
Breonia chinensis (Lam.) Capuron (**Tree**)	Jabon	Stem: House	Indian, Malesian
Nauclea orientalis (L.) L. (**Tree**)	Bengkel	Stem: House, Barn	Malesian, Northeastern Australian
Hypobathrum frutescens Blume (**Tree**)	Kayu api	Stem: Religious Use [Balinese Hindu temple], House	Indochinese, Malesian
Rutaceae			
Melicope glabra (Blume) T.G. Hartley (**Tree**)	Sampang	Stem: House	Malesian
Murraya paniculata (L.) Jack (**Shrub**)	Kemuning	Stem: Religious Use [Balinese Hindu temple]	Indochinese, Indian, Malesian, Northeast Australian
Santalaceae			
Santalum album L. (**Tree**)	Cendana	Stem: Religious Use [Balinese Hindu temple]	Indian
Sapindaceae			
Allophylus cobbe (L.) Raeusch. (**Shrub**)	Iseh	Stem: Stable [Cowshed, Pigpen]	Malesian
Sapotaceae			
Madhuca motleyana (de Vriese) J.F.Macbr. (**Tree**)	Nyantuh	Stem: Stable [Cowshed, Pigpen]	Malesian

Source: Sujarwo and Keim (2017)

D. Religious Offerings

Balinese Hinduism is basically a harmonious syncretism between the imported Aryan-Indian Hinduism and indigenous Austronesian belief, which is actually brought to the island of Bali by the Javanese Majapahit people, who took refuge in Bali from neighboring Java island around the end of Majapahit Empire, around 16th century AD. In fact, the Austronesian tradition is more dominant than the original Aryan-Sanskrit based Hinduism created in India, so much that Balinese Hinduism is basically Hinduism with a strong flavor of local Austronesian religion and tradition. Thus, it is regarded here that Balinese Hinduism –in some ways– reflects the ancient Austronesian civilization or at least the pre-Islamic Austronesia. This is also indicated by the incorporation of Austronesian religious related tradition, for example the offerings, especially the species composition selected and implemented in the important 'Five Holy Ceremonies' or *Panca yadnya*.

Plants constitute fundamental elements of these offerings. We can see plant offerings everywhere in Bali, especially the *Canangsari* (Figure 4.2), a tiny coconut leaf basket filled with rice, fruit, and flowers, often in front of houses, shops, hotels and even on cars and motorbikes. There are more elaborate offerings in shrines and temples (Figure 4.3), and even large offerings, such as the *penjor*, a three-meter bamboo culm with many elements attached for decoration used in special ceremonies (i.e., *galungan* feast celebration) (Eiseman, 1990).

Regarding the activities in the forests, they always start and finish with praying in the small shrines usually established in the gate before entering the forests or even in the middle of the forests, which are regarded sacred by the people. Offerings are always presented there by the devotees echoing the Austronesian traditions practiced from throughout Indonesian Archipelago up to the Pacific.

Photo: Wawan Sujarwo (2019)

Figure 4.2 Example of offerings in Balinese Hinduism, *Canangsari* is one of the daily offerings.

(A) The shrines established in the gate; (B) The shrines established in the middle

Photo: Ary Prihardhyanto Keim (2014)

Figure 4.3 The shrines of the forests with offerings can be seen in the forests of Dauh Waru, Jembrana.

Sujarwo et al. (2020) noted the use of 125 species of plants (including 148 plant parts) from 112 genera and 49 families that are used in rituals of offerings in Bali. There are 67 wild and semi-wild species, 63 cultivated species, and five species are both wild and cultivated (Table 4.3). Six families were considered particularly important in the *Panca yadnya* by the local inhabitants, i.e., *Poaceae* (15 species), *Fabaceae* (12 species), *Zingiberaceae* (8 species), *Arecaceae* (6 species), *Phyllantaceae* (5 species), and *Apocynaceae* (5 species).

The dominant life forms are trees, followed by herbs, shrubs, and climbers. The number of plant species used in the *Panca yadnya* is quite variable, i.e., *Pitra yadnya* with 118 species (136 plant parts), followed by *Bhuta yadnya*, *Dewa yadnya*, *Manusa yadnya*, and *Rsi yadnya*. The most frequently used parts are the leaves followed by fruits and other plant parts.

Most plant parts are collected throughout the year. 125 recorded species include tropical plants (77%), subtropical plants (18%), and temperate plants (5%), of which 71.2% are native to the Malesian floristic region, 38.4% to the Indo-chinese floristic region, and 34.4% to the Indian floristic region. The considerable percentage of species of the Malesian region is possibly influenced culturally. Sujarwo et al. (2020) recorded 36 species that are not native to the Malesian region.

Plant species present in the offerings are often native (Girmansyah et al., 2013) or easily reachable by the Balinese because they are cultivated in home gardens or commonly sold in traditional markets (Sujarwo et al., 2020). Moreover, alien species (e.g., *Celosia spicata*, *Eleusine indica*, *Imperata cylindrica*, *Phyllanthus niruri*) are well-known and frequently used by the Balinese. Among the non-indigenous species, it is noteworthy to mention the coincidence of the first appearance of the Indian region species in Indonesia

(e.g., *Cajanus cajan*, *Cucumis sativus*, *Momordica charantia*, *Solanum melongena*, *Tabernaemontana divaricata*) with the introduction of religious and cultural Indian influences in the eighth century (Rao, 2001). Other plants were incorporated later into the offering. For instance, the Dutch were responsible for the introduction of plants native to Central and South America (e.g., *Arachis hypogea*, *Capsicum annuum*, *Carica papaya*, *Manihot esculenta*, *Plumeria alba*, *Psidium guajava*, and *Tagetes erecta*) during the sixteenth century (Simmonds, 1976). Also, the selection of species (Silva et al., 2018) seems to follow the criteria (e.g., aesthetic such as colors, shapes, smell; apotropaic; curative; food; function) based on the knowledge on the local flora, occurrence and abundance in the natural environment, common presence in home gardens, and old traditional uses.

Apart from various species of plants implemented in the offerings, there is one species that always occurs in every composition, e.g coconut (*Cocos nucifera*). It is regarded as a piece of strong supporting evidence that despite originating from Indian, the Balinese Hinduism outstandingly still keeps most of its Austronesian traditions intact.

Table 4.3 Plants Used in Balinese Religious Offerings

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Acanthaceae								
Asystasia mysorensis (Roth) T. Anderson (**Herb**)	Knuja	Leaves						Guineo-Congolian, Karoo-Namib, Sudano-Zambezian, Uzambara-Zululand
Barleria prionitis L. (**Herb**)	Landep-landep	Leaves	✓					Indian, Guineo-Congolian, Karoo-Namib, Madagascan, Sudano-Zambezian, Uzambara-Zululand
Graptophyllum pictum (L.) Griff. (**Herb**)	Temen	Leaves	✓	✓	✓	✓	✓	Malesian
Justicia gendarussa Burm.F. (**Shrub**)	Dusakiling	Leaves	✓	✓	✓	✓	✓	Indian, Indochinese, Malesian
Achariaceae								
Pangium edule Reinw. (**Tree**)	Pangi	Fruit	✓	✓	✓	✓	✓	Fijian, Indian, Malesian, Polynesian

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Amaranthaceae								
Celosia spicata Spreng. (**Shrub**)	Keniwan	Flower		✓				Andean, Brazilian, Carribean, Guineo-Congolian, Indian, Indochinese, Madagascan, Malesian, Region of Guayana Highlands, Sudano-Zambezian, Uzambara-Zululand
Gomphrena globosa L. (**Shrub**)	Ratna	Flower	✓	✓	✓			Carribean
Amaryllidaceae								
Allium cepa L. (**Herb**)	Bawang merah	Tuber	✓	✓	✓	✓	✓	Irano-Turanian
Allium sativum L. (**Herb**)	Bawang putih/ kesuna	Tuber	✓	✓	✓	✓	✓	Irano-Turanian
Anacardiaceae								
Mangifera caesia Jack (**Tree**)	Wani/poh	Fruit	✓	✓	✓	✓	✓	Malesian

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Annonaceae								
Cananga odorata (Lam.) Hook.f. & Thomson (**Tree**)	Sandat	Flower	✓	✓	✓		✓	Malesian
Apocynaceae								
Hoya heuschkeliana Kloppenb. (**Climber**)	Tebel-tebel	Leaves	✓					Malesian
Plumeria alba L. (**Tree**)	Jepun	Flower	✓	✓	✓	✓	✓	Caribbean
Alstonia scholaris (L.) R. Br. (**Tree**)	Polegamongan/pulai	Leaves		✓		✓		Indian, Indochinese, Malesian, Northeastern Australian
Calotropis gigantea (L.) Dryand. (**Shrub**)	Medori putih	Flower		✓				Indian, Indochinese, Malesian
Nerium oleander L. (**Shrub**)	Kenyeri putih	Flower		✓	✓			Eastern Asiatic, Indian, Mediterranean, Saharo-Arabian Region, Sudano-Zambezian

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Tabernaemontana divaricata (L.) R.Br. ex Roem. & Schult. (**Shrub**)	Tuludnyuh	Flower		✓				Indian
Araceae								
Colocasia esculenta (L.) Schott (**Shrub**)	Keladi/don kembang	Tuber	✓	✓	✓			Indian, Indochinese, Malesian
Araliaceae								
Schefflera elliptica (Blume) Harms (**Climber**)	Tulak	Wood		✓		✓		Indian, Indochinese
Arecaceae								
Areca catechu L. (**Tree**)	Pinang	Fruit	✓	✓	✓	✓	✓	Malesian
Arenga pinnata (Wurmb) Merr. (**Tree**)	Aren/jaka/ beluluk/ enau	Leaves	✓	✓	✓	✓	✓	Indian, Indochinese, Malesian
		Fruit			✓			
		Black fibres	✓					
		Sap				✓		

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Caryota mitis Lour. (Tree)	Dudu	Stem	✓	✓	✓	✓	✓	Indochinese, Malesian
Cocos nucifera L. (Tree)	Kelapa/ nyuh gading/nyuh gadang/ nyuh sudamala	Fruit	✓	✓	✓	✓	✓	Indian, Malesian
		Leaves	✓	✓	✓	✓	✓	
		Midrib				✓		
Pinanga coronata (Blume ex Mart.) Blume (Tree)	Peji	Stem	✓	✓	✓	✓	✓	Indian, Malesian
Salacca zalacca (Gaertn.) Voss (Shrub)	Salak	Fruit	✓	✓	✓	✓	✓	Malesian
		Leaves		✓				
Asparagaceae								
Cordyline fruticosa (L.) A.Chev. (Shrub)	Andong bang	Leaves		✓		✓		Fijian, Indochinese, Malesian, Northeast Australian, Polynesian

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Dracaena angustifolia (Medik.) Roxb. (Shrub)	Kayu sugih	Leaves	✓	✓	✓	✓	✓	Fijian, Indochinese, Malesian, Northeast Australian, Polynesian
Athyriaceae								
Diplazium esculentum (Retz.) Sw. (Herb)	Paku jukut	Leaves	✓	✓	✓			Eastern Asiatic, Indian, Indochinese, Malesian
Burseraceae								
Protium javanicum Burm.f. (Tree)	Tenggulun	Wood		✓		✓		Malesian
		Leaves		✓		✓		
Caricaceae								
Carica papaya L. (Tree)	Gedang/ pepaya	Fruit		✓		✓		Carribean
Clusiaceae								
Garcinia × *mangostana* L. (Tree)	Manggis	Fruit	✓	✓	✓	✓	✓	Indochinese, Malesian
		Leaves	✓	✓	✓			
Compositae								

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Blumea balsamifera (L.) DC. **(Tree)**	Sembung	Leaves		✓		✓		Eastern Asiatic, Indian, Indochinese, Malesian
Cosmos sulphureus Cav. **(Herb)**	Padang berman	Leaves		✓				Caribbean, Madrean
Tagetes erecta L. **(Herb)**	Gumitir	Flower	✓	✓	✓	✓	✓	Madrean
Cucurbitaceae								
Benincasa hispida (Thunb.) Cogn. **(Climber)**	Blego	Fruit		✓				Indian, Indochinese, Malesian
Cucumis sativus L. **(Climber)**	Ketimun	Fruit	✓	✓	✓	✓	✓	Indian
Cucurbita pepo L. **(Climber)**	Waluh/labu	Leaves		✓				Madrean
		Fruit		✓				
Momordica charantia L. **(Climber)**	Paya	Leaves		✓		✓		Indian
		Fruit		✓		✓		

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Dioscoreaceae								
Dioscorea alata L. (**Climber**)	Ubi aung/ ubi liyan	Tuber		✓	✓	✓		Indochinese, Malesian
Dioscorea hispida Dennst. (**Climber**)	Gadung	Flower	✓	✓	✓	✓	✓	Indian, Indochinese, Malesian, Northeast Australian
Euphorbiaceae								
Aleurites moluccanus (L.) Willd. (**Tree**)	Kemiri/ tingkih	Seeds	✓	✓	✓	✓	✓	Malesian
Manihot esculenta Crantz (**Shrub**)	Sela sawi/ ketela	Tuber	✓	✓	✓	✓	✓	Amazonian, Brazilian
Lamiaceae								
Elsholtzia pubescens Benth. (**Shrub**)	Junggul	Leaves		✓				Malesian
Plectranthus scutellarioides (L.) R.Br. (**Shrub**)	Reng-reng	Leaves	✓	✓		✓		Indochinese, Malesian

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Leguminosae								
Arachis hypogaea L. (**Herb**)	Kacang tanah	Seeds	✓	✓	✓	✓	✓	Amazonian, Andean, Brazilian
Caesalpinia pulcherrima (L.) Sw. (**Shrub**)	Kemerakan	Flower				✓		Caribbean
Cajanus cajan (L.) Millsp. (**Shrub**)	Undis	Seeds	✓	✓	✓	✓	✓	Indian
Canavalia gladiata (Jacq.) DC. (**Climber**)	Juleh	Leaves		✓				Indian, Indochinese, Guineo-Congolian, Malesian, Sudano-Zambezian, Uzambara-Zululand
Clitoria ternatea L. (**Climber**)	Teleng	Flower		✓				Indochinese, Malesian
Entada phaseoloides (L.) Merr. (**Climber**)	Cikal	Fruit	✓			✓		Eastern Asiatic, Malesian, Northeast Australian
Erythrina crista-galli L. (**Tree**)	Canging	Leaves		✓				Amazonian, Brazilian

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Erythrina subumbrans (Hassk.) Merr. (**Tree**)	Dadap tis	Leaves	✓	✓	✓	✓	✓	Indian, Indochinese, Malesian
		Wood	✓	✓	✓	✓	✓	
Lablab purpureus (L.) Sweet (**Climber**)	Komak	Seeds	✓	✓	✓	✓	✓	Guineo-Congolian, Saharo-Arabian, Sudano-Zambezian, Uzambara-Zululand
Psophocarpus tetragonolobus (L.) DC. (**Climber**)	Botor	Seeds		✓	✓	✓		Malesian
Pueraria phaseoloides (Roxb.) Benth. (**Climber**)	Ucu	Seeds	✓	✓	✓	✓	✓	Indian, Indochinese, Malesian
Vigna unguiculata (L.) Walp. (**Climber**)	Kacang panjang	Fruit	✓	✓	✓	✓	✓	Guineo-Congolian
Lygodiaceae								

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Lygodium circinnatum (Burm. f.) Sw. **(Climber)**	Paku ata	Leaves		✓	✓	✓		Eastern Asiatic, Fijian, Indian, Indochinese, Malesian
Lythraceae								
Punica granatum L. **(Shrub)**	Delima	Fruit	✓	✓	✓	✓	✓	Irano-Turanian
Magnoliaceae								
Michelia x alba DC. **(Tree)**	Cempaka	Flower	✓		✓		✓	Indian, Indochinese, Malesian
Malvaceae								
Durio zibethinus L. **(Tree)**	Durian	Fruit	✓	✓	✓	✓	✓	Malesian
		Leaves		✓				
Hibiscus rosa-sinensis L. **(Shrub)**	Pucuk bang	Flower		✓				Indian, Indochinese, Malesian
Melochia umbellata (Houtt.) Stapf **(Tree)**	Bentenu	Leaves		✓	✓			Indian, Malesian
		Bark		✓				
		Wood		✓	✓			
Marantaceae								

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Maranta arundinacea L. (**Shrub**)	Celengidi	Leaves		✓				Amazonian, Andean, Brazilian, Caribbean, Madrean, Region of the Guayana Highlands
Meliaceae								
Lansium parasiticum (Osbeck) K.C.Sahni & Bennet (**Tree**)	Ceroring	Fruit	✓	✓	✓	✓	✓	Malesian
		Bark			✓			
Dysoxylum parasiticum (Osbeck) Kosterm. (**Tree**)	Majagau	Wood	✓	✓	✓	✓	✓	Eastern Asiatic, Fijian, Malesian, Northeast Australian
Sandoricum koetjape (Burm.f.) Merr. (**Tree**)	Sentul	Fruit		✓		✓		Indochinese, Malesian
Moraceae								
Artocarpus heterophyllus Lam. (**Tree**)	Nangka	Fruit	✓	✓	✓	✓	✓	Indian, Malesian

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Ficus benjamina L. (**Tree**)	Bingin	Leaves		✓				Indian, Indochinese, Malesian, Northeast Australian
Moringaceae								
Moringa oleifera Lam. (**Tree**)	Kelor	Leaves		✓				Indian
Musaceae								
Musa x paradisiaca L. (**Herb**)	Pisang/ biu/ dak/ biu susu/ biu mas/ biu raja/biu kayu/biu bunga/biu gancah/biu tembaga	Fruit	✓	✓	✓	✓	✓	Indian, Indochinese, Malesian
		Leaves	✓	✓	✓	✓	✓	
Myrtaceae								
Psidium guajava L. (**Tree**)	Sotong	Fruit	✓	✓	✓	✓	✓	Amazonian, Andean, Brazilian, Caribbean, Region of the Guayana Highlands

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Syzygium polycephalum (Miq.) Merr. & L.M.Perry (**Tree**)	Kaliasem	Fruit		✓	✓			Malesian
Nephrolepidaceae								
Nephrolepis cordifolia (L.) C. Presl (**Herb**)	Paku pipid/ paku lipan	Leaves	✓	✓		✓		Northeast Australian
Nymphaeaceae								
Nymphaea lotus L. (**Herb**)	Tunjung	Flower	✓	✓	✓	✓	✓	Madagascan, Saharo-Arabian, Sudano-Zambezian
Pandanaceae								
Pandanus tectorius Parkinson ex Du Roi (**Shrub**)	Pandan/ pudak	Leaves	✓	✓	✓	✓	✓	Fijian, Malesian, Northeast Australian
Phyllanthaceae								

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Antidesma bunius (L.) Spreng. (**Tree**)	Buni	Fruit	✓	✓	✓			Malesian, Northeastern Australian
Baccaurea racemosa (Reinw. ex Blume) Müll. Arg. (**Tree**)	Kepundung	Fruit	✓	✓	✓	✓	✓	Indochinese, Malesian
		Leaves		✓				
Phyllanthus emblica L. (**Tree**)	Kalimoko	Fruit		✓		✓		Indochinese, Malesian
		Leaves		✓				
Phyllanthus buxifolius (Blume) Müll. Arg. (**Shrub**)	Sisih	Wood		✓		✓		Malesian
Phyllanthus niruri L. (**Shrub**)	Menirang	Leaves		✓				Amazonian, Andean, Brazilian, Caribbean, Region of the Guayana Highlands
Piperaceae								
Piper betle L. (**Climber**)	Sirih	Leaves	✓	✓	✓	✓	✓	Malesian

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Poaceae								
Bambusa vulgaris Schrad. (**Tree**)	Tiing ampel gading	Culm		✓				Eastern Asiatic
Coix lacryma-jobi L. (**Herb**)	Jali-jali	Seeds		✓		✓		Eastern Asiatic, Indochinese, Malesian
Cynodon dactylon (L.) Pers. (**Herb**)	Padang lepas	Leaves		✓				Madagascan, Sudano-Zambezian, Uzambara-Zululand
Dendrocalamus asper (Schult.) Backer (**Tree**)	Tiing jelepung	Culm	✓	✓	✓	✓	✓	Malesian
Eleusine coracana (L.) Gaertn. (**Herb**)	Godem	Seeds		✓		✓		Sudano-Zambezian
Eleusine indica (L.) Gaertn. (**Herb**)	Padang belulang	Leaves		✓				Eastern Asiatic, Indian, Indochinese, Guineo-Congolian, Karoo-Namib, Madagascan, Malesian, Saharo-Arabian, Sudano-Zambezian, Uzambara-Zululand

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Gigantochloa apus (Schult.) Kurz (**Tree**)	Tiing tali	Culm	✓	✓	✓	✓	✓	Indochinese
Gigantochloa baliana Widjaja & Astuti (**Tree**)	Tiing bali	Culm		✓				Malesian
Imperata cylindrica (L.) Raeusch. (**Herb**)	Lalang	Leaves	✓	✓	✓	✓	✓	Central Australian, Eastern Asiatic, Indochinese, Karoo-Namib, Madagascan, Malesian, Northeastern Australian, Southwest Australian, Sudano-Zambezian
Oryza sativa L. (**Herb**)	Padi/padi gaga/ketan/ injin	Seeds	✓	✓	✓	✓	✓	Indochinese
Panicum miliaceum L. (**Herb**)	Jawe	Seeds	✓	✓				Eastern Asiatic, Irano-Turanian
Saccharum officinarum L. (**Herb**)	Tebu cemeng	Stem	✓	✓	✓	✓	✓	Indochinese, Malesian

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Schizostachyum brachycladum (Kurz) Kurz (**Tree**)	Tiing buluh gading/ tamblang	Culm		✓		✓		Indochinese, Malesian
Schizostachyum lima (Blanco) Merr. (**Tree**)	Tiing buluh	Culm		✓		✓		Malesian
		Leaves		✓		✓		
Sorghum bicolor (L.) Moench (**Herb**)	Jagung kedu	Seeds		✓				Sudano-Zambezian
Pteridaceae								
Pityrogramma calomelanos (L.) Link (**Herb**)	Paku suda-mala	Leaves		✓				Amazonian, Andean, Brazilian, Caribbean, Region of Guayana Highlands
Rosaceae								
Rubus buergeri Miq. (**Shrub**)	Gunggung bukit	Leaves		✓				Eastern Asiatic

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Rubus rosifolius Sm. (**Shrub**)	Gunggung bali/ lengis	Leaves		✓		✓		Eastern Asiatic, Indian
Rubiaceae								
Gardenia jasminoides J.Ellis (**Shrub**)	Jempiring	Flower	✓	✓	✓	✓	✓	Eastern Asiatic, Indochinese
		Leaves	✓	✓				
Morinda citrifolia L. (**Tree**)	Tibah	Fruit	✓	✓	✓	✓	✓	Central Australian, Malesian, Northeastern Australian, Southwest Australian
Neonauclea calycina (Bartl. ex DC.) Merr. (**Tree**)	Daun bengkel	Leaves		✓				Eastern Asiatic, Indian, Indochinese, Malesian, Northeastern Australian
Rutaceae								
Citrus × aurantium L. (**Tree**)	Semaga	Fruit	✓	✓	✓	✓	✓	Malesian
Citrus maxima (Burm.) Merr. (**Tree**)	Jeruk	Fruit	✓	✓	✓	✓	✓	Indochinese, Malesian

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Murraya koenigii (L.) Spreng. (**Tree**)	Pupug	Wood		✓				Indian
Santalaceae								
Santalum album L. (**Tree**)	Cendana	Wood	✓	✓	✓	✓	✓	Indian, Malesian
Sapindaceae								
Nephelium lappaceum L. (**Tree**)	Buluan/ rambutan	Fruit	✓	✓	✓	✓	✓	Indochinese, Malesian
		Leaves		✓				
Sapotaceae								
Manilkara zapota (L.) P.Royen (**Tree**)	Sawo	Fruit	✓	✓	✓	✓	✓	Caribbean
Selaginellaceae								
Selaginella delicatula (Desv. ex Poir.) (**Herb**)	Bekenying	Leaves	✓	✓				Eastern Asiatic, Indian, Indochinese, Malesian
Solanaceae								

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Capsicum annuum L. **(Shrub)**	Cabai/tabia	Fruit	✓	✓	✓	✓	✓	Amazonian, Andean, Brazilian, Caribbean, Madrean, Region of Guayana Highlands
Solanum melongena L. **(Shrub)**	Tuwung/ terung	Fruit		✓				Indian, Indochinese
Styracaceae								
Styrax benzoin Dryand. **(Tree)**	Menyan	Wood	✓	✓	✓	✓	✓	Indochinese, Malesian
Urticaceae								
Boehmeria nivea (L.) Gaudich. **(Shrub)**	Bagu	Leaves		✓				Eastern Asiatic
Dendrocnide stimulans (L.f.) Chew **(Tree)**	Lateng	Leaves		✓				Indochinese, Malesian
		Wood		✓				
Leucosyke capitellata Wedd. **(Tree)**	Patih kalah	Leaves		✓				Fijian, Malesian
Vitaceae								

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Cissus javana DC. (**Climber**)	Dinding ai	Whole part	✓					Indian, Indochinese, Malesian
Leea angulata Korth. ex Miq. (**Shrub**)	Kelawasan	Leaves		✓				Malesian
Zingiberaceae								
Alpinia galanga (L.) Willd. (**Herb**)	Isen/ lengkuas	Tuber	✓	✓	✓	✓	✓	Malesian
Amomum maximum Roxb. (**Herb**)	Kase	Fruit		✓				Indian, Indochinese, Malesian
Curcuma viridiflora Roxb. (**Herb**)	Kunir/kunyit	Tuber	✓	✓	✓	✓	✓	Indochinese, Malesian
Curcuma zedoaria (Christm.) Roscoe (**Herb**)	Kepanggean	Leaves		✓				Indian, Malesian
		Tuber		✓				
Etlingera elatior (Jack) R.M.Sm. (**Herb**)	Kecicang	Flower	✓					Malesian

Plant Families & Species, (Life Form)	Vernacular Names	Used Parts	Use in *Yadnya*					Floristic Region
			Dewa yadnya	*Pitra yadnya*	*Manusa yadnya*	*Bhuta yadnya*	*Rsi yadnya*	
Kaempferia rotunda L. **(Herb)**	Cekuh/kencur	Tuber	✓	✓	✓	✓	✓	Eastern Asiatic, Indian, Indochinese, Malesian
Zingiber montanum (J.Koenig) Link ex A.Dietr. **(Herb)**	Gamongan	Tuber		✓		✓		Malesian
Zingiber officinale Roscoe **(Herb)**	Jahe	Tuber	✓	✓	✓	✓	✓	Indian, Indochinese, Malesian

Source: Sujarwo et al. (2020)

Notes: 1) *Bhuta yadnya* is a ceremony of offerings to spirits and demons, i.e. *Pengerupukan* by burning a giant puppet (*ogoh-ogoh*) on the day before Silent Day (Nyepi), 2) *Dewa yadnya* is a set of rituals to worship gods and deities, i.e., the recurrent ceremonies of the full moon and new moon, the annual Silence Day, and several bi-annual ceremonies including *Galungan* and *Kuningan* (both are relevant feasts for Hindus in Bali; *Galungan* refers to the time when the ancestral spirits visit the Earth. The last day of the celebration is *Kuningan*, when they return), 3) *Manusa yadnya* is intended to celebrate the different stages of human life. There are 13 ceremonies in *Manusa yadnya* that use plants as symbols. They include the tooth filing ceremony—where the upper front teeth are filed flat—and are performed to rid the spirit of the six negative emotions in humans (lust, greed, anger, confusion, drunkenness and jealousy), 4) *Pitra yadnya* is a ceremony for death and reincarnation. This ceremony aims to restore the body and soul to their place of origin through burial or cremation (*Ngaben*). Various plants are used during this ritual. 5) *Rsi yadnya* is a consecration of the clergy and it is carried out with the nomination of a new priest. Reed leaves are often tied around the head of the celebrated priest.

E. Ethnobotany of Bamboo

Dransfield (1981) estimated that sixty-four percent of world bamboo species are native to Southeast Asia, thirty-three percent of it grow in Central and South America, while the rest is in Africa and Oceania. In Indonesia, over 100 bamboo species are mostly found in Sumatra, Java, Bali, and the Lesser Sunda Islands (Dransfield & Widjaja, 1995; Widjaja, 2001; Widjaja et al., 2005). This geographical derivation might be strongly in connection with cultural influences. Pringle (2004), and Sujarwo and Caneva (2016) mentioned that the island of Bali is not only a species-rich tropical area, but also rich with cultural history. On the contrary, the plants arrival in Indonesia native to Central and South America was led by seed exchange among botanic gardens, and might have been introduced by the Dutch starting in the 16th century (Simmonds, 1976).

Even though the surface area of Bali Island is around 5,780 km^2, and only 0.2% of the whole area of Indonesia, six bamboo species were identified native to the island. They are *Bambusa ooh* Widjaja & Astuti, *Dinochloa sepang* Widjaja & Astuti, *Gigantochloa aya* Widjaja & Astuti, *Gigantochloa baliana* Widjaja & Astuti, *Gigantochloa taluh* Widjaja & Astuti, and *Schizostachyum castaneum* Widjaja (Arinasa & Sujarwo, 2015). Arinasa and Peneng (2013) stated that not all bamboo species on the island have been identified yet. In Bali, bamboo generally grows in natural forests and home gardens. One of the well-known bamboo forests is situated in Penglipuran traditional village, a large area of bamboo belongs to the local communities and individual landowners, and it varies between 40 and 50 hectares (Sujarwo, 2016).

There is a uniqueness of bamboo in Bali Island. Bamboo represents one of three living philosophies of the Balinese. Bamboo is an integral part of Bali life, particularly in the rural populations. Coconut and banana are also used, but

less commonly. The people of Bali depend upon bamboo for every aspect of life from birth to death. For instance, Balinese utilize the bamboo as a knife to cut the navel when a baby is born, and bamboo is used to transport the body of an individual to the cemetery upon his demise (Sujarwo et al., 2012).

Learning the indigenous knowledge in every region regarding the utilization of bamboo will be useful to understand cultural values. In spite of the same bamboo species, the parts that are used, the preparation and application methods are not the same in every region. These depend upon the local wisdom and culture in every region (Sujarwo et al., 2014). Considering the diversity of bamboo, discovering its unusual uses could be valuable. This could be done not only in Bali, and many scientists could take a role in this. It is possible that bamboo could become an industry worth millions of dollars, because of its rapid productivity and ease of cultivation in many environments.

History and folklore

In the past, *Bambusa blumeana* grew abundantly throughout the coastline of the northern part of Bali Island. It formed a natural barrier, which prevented the Dutch from entering the island when they wanted to colonize Singaraja (the former capital city of Bali) (Sujarwo, 2018). According to the Balinese folklore, the Dutch threatened Singaraja many times, but they could not enter Singaraja due to *Bambusa blumeana*. Therefore, Singaraja could not be colonized by the Dutch for a long time. However, the Dutch were very smart and they were relentless in their quest to colonize Singaraja, hence they always devised new techniques to accomplish their goals. They came up with the idea of destroying the forest of *Bambusa blumeana*, where it grew well and was sturdy. Many coins (money) were thrown at

the bamboo forest over a long period of time. Local people were overjoyed at this, because they did not have much money. As a result, they began to cut down all clumps of *Bambusa blumeana* throughout the coastline in pursuit of these coins. The livelihood of the Balinese people living in Singaraja gradually began to change. Consequently, this provided an opportunity for the Dutch to clear the forest of *Bambusa blumeana*. Once it had been removed from the coastline, the area became vulnerable and the Dutch moved in easily. The Dutch used weaponry and warships to attack Singaraja. In the end, they were able to colonize Singaraja. The local people were saddened by this because they were too late to realize that the Dutch had used this strategy to conquer them.

Folk feast

Galungan is one of the biggest feasts for Hindus in Bali, as are the *Nyepi* and *Kuningan* days. Bali's Hindus celebrate *Galungan* twice a year, as well as *Kuningan* while *Nyepi* is held only once a year. A day before the day of *Galungan*, Balinese Hindus set *Penjor* in front of their own houses (Sujarwo, 2011). *Penjor* is made from the whole bamboo culms and decorated with an assortment of ornaments at its curved ends. *Penjor* is one of the most important tools in the Galungan's ceremony. This has resulted in increasing demand of bamboo in Bali, which affects the selling price in the market. The significance of *Penjor* is as a token of gratitude for blessings that have been given and also as an offering to God that is symbolized in all the crops used in it. *Penjor* is always installed on a day before *Galungan* and attached in front of the entrance of the house with its end facing the street. It is removed a month after the day of *Galungan*. The types of bamboo that are often used to make *Penjor* are *bambu bali* (*Gigantochloa baliana*), *bambu tali*

(*Gigantochloa apus*), *bambu tabah* (*Gigantochloa nigrociliata*), and *bambu tamblang gading* (*Schizostachyum brachycladum*) (Sujarwo, 2011). *Bambu bali* is Bali endemic species that has been cultivated in many local communities in Bali and has been conserved in the Bali Botanic Garden.

Bamboo and myths

Bambu pingit (*Gigantochloa hasskarliana*) is well-known to the indigenous people in eastern parts of Bali (Sujarwo, 2018). It can only be found in the holy area of the *Lempuyang Luhur* temple, which is one of the biggest temples in Bali. It is located on the mountain *Lampuyang Luhur*, which is 1,200 masl. The local people in this area believe that this bamboo can cure breast cancer, insomnia, and heart problems. According to a Hindu priest at the temple, the water inside the culms of this bamboo can cure those diseases. Local people also said that many have been healed by drinking it. In addition to being used as a medicine, it is also used as holy water by Hindu people in Bali (Sujarwo, 2018). This is an example of local indigenous knowledge. On top of this mountain, five clumps of *bambu pingit* are growing. While bamboos can grow from the lowlands to the highlands, this bamboo only grows on top of this mountain.

The roof of Balinese traditional buildings

Most Balinese have known that clay was usually used as raw material for the roof. However, in Penglipuran traditional village in Bali, the roof is unique. It is made from laths of bamboos (*Gigantochloa taluh* and *Gigantochloa apus*) with dimensions of 5–7 cm wide, 25–54 cm long, and 0.5–1.2 cm thick respectively. In Penglipuran, most holy buildings such as *pura* (temple), *bale gong*, *bale piasan*, *bale kulkul*, and *bale paruman* (these holy buildings are parts of the Hindu temple) have bamboo roofs. Besides holy buildings, houses, kitchens,

and *angkul-angkul* (private entrance gates) also use bamboo for roofs, especially from *bambu aya* (*Gigantochloa aya*).

The utilization of bamboo for roofs is found not only in Penglipuran (Bangli regency) but also in other villages in Bali, such as Tigawasa and Sidatapa villages (Bulleleng regency), Angsri and Wongaya Gede villages (Tabanan regency), Pempatan and Tenganan villages (Karangasem regency). Arinasa and Peneng (2013) stated that, in recent times, restaurants, hotels, and houses in Bali have utilized the laths of bamboo for the roof. Making and preserving bamboo laths is simple. Although the bamboo roof is made traditionally and without using any preservative, many people began to like it because of the freshness it gives off. The air circulation is also better. In addition, the bamboo roof has been reported to lasting for 25-30 years or more (Sujarwo 2018).

Bamboo Charcoal

Sujarwo (2018) recorded that in Bangli regency only, 18 species of bamboo grow. These include *Gigantochloa aya*, *Gigantochloa taluh*, *Gigantochloa apus*, and *Dendrocalamus asper*. Those bamboos have been utilized by traditional charcoal makers to produce charcoal. This is a product that has been developed in a sustainable way. It could be made from all parts of bamboo, but the traditional charcoal maker only uses bamboo waste. This includes rhizomes, internodes, small branches, and waste from the bamboo home industry. A few iron makers still exist in Bali. They burn bamboo charcoal to make knives, sickles, etc. They said that bamboo charcoal yields higher heat than other kinds, such as those made from coconut shells. This may be due the high silica content in bamboo. Bamboo has a significant impact and is used in many aspects of the lives of local people, particularly in the Bangli Regency.

According to Sujarwo (2018), bamboo charcoal usually sells for 60,000 IDR per sack (1 USD = 14,500 IDR). Traditional charcoal makers can make five sacks in two days, for which they will get IDR 300,000. However, they must buy the bamboo waste from craftsmen for IDR 30,000 for one sack. Therefore, the traditional charcoal makers get only IDR 150,000 for two days or IDR 75,000 for one day. They do not earn much, although this is a bit higher than for day workers because labor pay is usually about IDR 50,000 to IDR 60,000 per day.

Bamboo and medicine

The use of modern medicines and pharmaceuticals has spoiled humans, thus the knowledge of ancestral traditional medicines has been slightly overlooked. One potential alternative medicine material is bamboo. Bamboo is well-known, but its utilization as medicine is less known. Previously, the shoots of *bambu kuning* (*Bambusa vulgaris*) were used to heal liver problems (Sujarwo et al., 2012). Balinese ancestors used the water in *Dinochloa scandens* as medicinal eyewash and for tuberculosis (Tengah et al., 1995). Sujarwo et al. (2012) mentioned that some indigenous knowledge of bamboo was found through interviews with *Balian Usada*, an indigenous medical practitioner who is knowledgeable on plant uses, and eight species were found as medicine. The eight species of bamboo and their medicinal uses were: shoots of *Dendrocalamus asper*, used to reduce hypertension; shoots of *Gigantochloa nigrociliata*, used to relax muscle and for heartburn; roots of *Gigantochloa aya*, used to reduce fever; culms of *Bambusa vulgaris*, used to cure liver problem; shoots of *Schizostachyum lima* used to increase memory; shoots of *Bambusa vulgaris* var. *striata*, used to cure liver problems; roots of *Schizostachyum brachycladum*, used to smoothen mother's milk (Sujarwo et al., 2010a; Sujarwo,

2018); and roots and culms of *Gigantochloa apus*, used to cure diabetes and for skin rejuvenation (Sujarwo et al., 2010b). We need to learn the indigenous knowledge in every region about utilization of bamboo for medicine, among other plants. Even for the same species, the parts used and the preparation and application methods are not the same in every region as they depend upon local wisdom and customs. Considering the diversity of bamboo, discovering its use in medicine could be valuable, not only in Bali, and many scientists could take a role in this. Bamboo could become an industry worth billions of dollars in the medicinal world, because of its rapid productivity and ease of cultivation in many environments.

Bamboo shoots

Bamboo grows more rapidly than any other plant on the planet. It has been clocked surging skyward as fast as 47.6 inches in a 24-hour period, but it can only happen in the rainy season where shoots production becomes very abundant. However, there are only three types of bamboo shoots that are often traded in traditional markets in Bali, namely *bambu petung* (*Dendrocalamus asper*), *bambu tabah* (*Gigantochloa nigrociliata*), and *bambu tali* (*Gigantochloa apus*). Arinasa and Peneng (2013) stated that the first two species became very popular among local Balinese. Bamboo shoots contain a lot of protein, carbohydrates, fats, fibre, and vitamins A and C which are beneficial to the human body and health (Sujarwo et al. 2012). Although it has many health benefits, it is rare to find dishes made from bamboo shoots in fancy restaurants and hotels in Bali. There is a stigma in Balinese communities that bamboo shoots are food belong to the lower to middle-class society. Peak harvesting season of bamboo shoots occurs in January; this results to the fairly cheap selling price in traditional markets. The

bamboo shoots are sold at a price of 2,000 IDR per plastic bag (250 grams) (Sujarwo, 2015a). With many nutritional substances and health benefits, as well as prices that are relatively affordable, bamboo shoots are very important for local Balinese.

Creating a new water spring

Studies, conducted by Arinasa and Peneng (2013) and Sujarwo (2015b), indicated that the local inhabitants in several traditional villages in Bali, such as Angsri Village in Tabanan regency and Tigawasa Village in Bulleleng regency, believe that the bamboo forests that has existed for hundreds of years can create a new water spring. Such villages could be used as a model to show how a strong tradition of local communities, which has been passed down through generations of ancestors, could maintain bamboo forests for hundreds of years. The bamboo forests in such villages are mostly owned by indigenous communities and only a small fraction is owned by individuals. Local people only take a little direct benefit from selling bamboo culms because they believe that the soil and water conservation is much more important than the direct value of bamboo culms itself. However, the Environmental Bamboo Foundation Bali has received reports from many countries in the world that the flow of water in a region increases after a few years of planting bamboo and in some cases, new springs appear. This is not surprising, considering that bamboo is a C3 plant (the most efficient at photosynthesis in cool, wet climates) and very effective in water conservation. As a comparison, trees absorb an average of 35–40% rainwater, while bamboo can absorb up to 90%. That is the reason to why local people in Bali said that they plant water when they grow bamboo.

F. Quantitative Ethnobotany

Sujarwo and Caneva (2016) calculated the cultural food significance index (CFSI). They found that the values varied considerably from one species to another, with a minimum of 0.11 and a maximum of 1797.12. Applying the method of Pieroni (2001), it was possible to classify the cited plants into six groups of species with (1) very high significance (CFSI = 300 and over), (2) high significance (CFSI = 100–299), (3) moderate significance (CFSI = 20–99), (4) low significance (CFSI = 5–19), (5) very low significance (CFSI = 1–4), and (6) negligible significance (CFSI < 1). These groups varied in size, with the majority of plants belong to the very low significance group. The group with very high significance (CFSI = 300+) comprised mainly of edible fruits and seeds that were used in different preparations (*Arenga pinnata*, *Artocarpus heterophyllus*, and *Lablab purpureus*) with three other species (*Cinnamomum burmanni*, *Colocasia esculenta*, and *Piper betle*), which were known for the use of their leaves in vegetable soups and herbal drinks. The species included in this first category are those with the widest range of uses and contain medicinal properties. The inner stems of *Arenga pinnata* are edible when boiled, and considered as a staple food, the root decoction is used for urolithiasis, while the fruits are boiled and eaten as snacks. This plant tastes generally good and it scored high for parts used. The species included in the group with high significance (CFSI = 100–299) are typically used medicinally, as spices, or as cooked vegetable. The leaves of *Paederia scandens* are cooked and added to vegetable soups. The leaf decoction is used to treat fever and stimulate the appetite. A decoction of *Blumea balsamifera* leaves is used to treat diarrhea, fever, heartburn, and constipation. The group also included the commonly used spices: *Curcuma longa*, *Kaempferia galanga*, *Syzygium polyanthum*, and *Zingiber officinale*. The group

with moderate significance (CFSI = 20–99) consists of species that are used mainly as medicines or source of vegetable. Normally, they are used after basic preparation. They included the medicinal plants (*Alstonia scholaris*, *Andrographis paniculata*, *Averrhoa bilimbi*, *Centella asiatica*, *Hibiscus rosa-sinensis*, *Orthosiphon aristatus*, *Sauropus androgynus*, *Spondias pinnata*, *Zingiber montanum*), vegetables (*Carica papaya*, *Ipomoea batatas*, *Luffa acutangula*, *Manihot esculenta*, *Morus australis*, *Moringa oleifera*, *Musa paradisiaca*, *Sechium edule*), and a few fruit species (*Antidesma bunius*, *Punica granatum*, and *Syzygium samarangense*). This group also comprises the most frequently used staple food species, *Dioscorea hispida*. The group with low significance (CFSI = 5–19) consists of plants used as vegetables, consumed as edible fruit and seed, and used as medicine, staple foods, and spices. Good taste scores were reported for many of these species but their multi-functional food use and the number of parts used are generally very low. Species having low availability, low multi-functional food use, low parts used, and low food-medicinal role are classified in this class (very low significance with CFSI = 1–4). There are 44 species in this group. The taste score appreciation is good for some species, such as *Syzygium cumini*, *Annona muricata*, *Annona squamosa*, *Mangifera caesia*, *Manilkara zapota*, *Persea americana*, *Rubus rosifolius*, and *Sandoricum koetjape*. These species are well-known for their fruits. The group with a negligible significance rating (CFSI < 1) consists of all species that scored low on availability and parts used, has a very limited range of uses, and no recognized medicinal properties, as reported by two informants.

Sujarwo and Caneva (2016) also calculated the use value (UV), relative frequency of citation (RFC), relative importance (RI), cultural value (CVs), and informant consensus

factor (ICF). The mean value of the number of informants for each multiple use species was 10.52 (± 11.48) representing 21.04% of all the interviewees, but there was a relatively high variation between the number of informants for each species. Only thirteen species were cited by more than 30 informants (9.56%). The mean value for a number of citations for a given plant was 12.97 (± 16.05), implying that on average, a given species was cited 12.97 times (0.74% of all citations). In this case, only fifteen species were cited by more than 30 times (11.03%). On average, their study revealed that in general, the cultural values of the plants cited as useful was low, as suggested by the UV (0.26 ± 0.32), RFC (0.21 ± 0.23), and CVs (0.03 ± 0.09) indices. In addition, the mean value of RI (0.82 ± 0.31) indicated that the most versatile taxon, *Arenga pinnata*, (RI = 2.0) was 2.5 times more relevant than 106 other species. Nevertheless, some plants still possessed a relevant and shared cultural value. ICF values ranged between 0.88 and 0.95. This data indicated that informants tend to agree on the species to be used within all used categories. Moreover, values for CFSI, UV, RFC, RI, and CVs at intervals of 10%, demonstrated that the majority of cited plants were in the groups with low and very low significance values, and only a few plants had high and very high cultural values. This comparison also showed how the relative cultural value of plants was estimated differently from one index to another. In Sujarwo and Caneva (2016), *Colocasia esculenta* obtained the highest number of preferences for RFC, UV and CVs. *Arenga pinnata* was in first place for CFSI and RI. *Artocarpus heterophyllus*, *Lablab purpureus*, and *Cinnamomum burmanni* were also high in the CFSI, RI, and CVs (Table 4.4). ICF results revealed a well-defined food tradition.

Table 4.4 Ranking of the Top 20 Plant Species Considered to be the Most Important for the Community of Bali *Aga* Villages, Based on Five Quantitative Measures of Relative Importance

CFSI	UV	RFC	RI	CVs
Arenga pinnata	*Colocasia esculenta*	*Colocasia esculenta*	*Arenga pinnata*	*Colocasia esculenta*
Artocarpus heterophyllus	*Arenga pinnata*	*Manihot esculenta*	*Lablab purpureus*	*Arenga pinnata*
Lablab purpureus	*Cinnamomum burmanni*	*Artocarpus heterophyllus*	*Colocasia esculenta*	*Cinnamomum burmanni*
Colocasia esculenta	*Piper betle*	*Musa paradisiaca*	*Artocarpus heterophyllus*	*Artocarpus heterophyllus*
Cinnamomum burmanni	*Manihot esculenta*	*Blumea balsamifera*	*Cinnamomum burmanni*	*Piper betle*
Piper betle	*Artocarpus heterophyllus*	*Ipomoea batatas*	*Piper betle*	*Lablab purpureus*
Paederia foetida	*Lablab purpureus*	*Arenga pinnata*	*Antidesma bunius*	*Manihot esculenta*
Zingiber officinale	*Musa paradisiaca*	*Dioscorea hispida*	*Luffa acutangula*	*Musa paradisiaca*
Blumea balsamifera	*Blumea balsamifera*	*Cinnamomum burmanni*	*Syzygium polyanthum*	*Blumea balsamifera*
Kaempferia galanga	*Ipomoea batatas*	*Alstonia scholaris*	*Paederia foetida*	*Ipomoea batatas*
Syzygium polyanthum	*Paederia foetida*	*Psidium guajava*	*Artocarpus elasticus*	*Dioscorea hispida*

CFSI	UV	RFC	RI	CVs
Curcuma longa	*Dioscorea hispida*	*Piper betle*	*Kaempferia galanga*	*Alstonia scholaris*
Antidesma bunius	*Alstonia scholaris*	*Carica papaya*	*Averrhoa bilimbi*	*Psidium guajava*
Luffa acutangula	*Psidium guajava*	*Moringa oleifera*	*Curcuma longa*	*Carica papaya*
Alstonia scholaris	*Carica papaya*	*Cajanus cajan*	*Morus australis*	*Antidesma bunius*
Centella asiatica	*Luffa acutangula*	*Diplazium esculentum*	*Sauropus androgynus*	*Paederia foetida*
Ipomoea batatas	*Moringa oleifera*	*Centella asiatica*	*Nicolaia speciosa*	*Cajanus cajan*
Carica papaya	*Cajanus cajan*	*Sechium edule*	*Morus alba*	*Diplazium esculentum*
Manihot esculenta	*Diplazium esculentum*	*Zingiber montanum*	*Zingiber officinale*	*Luffa acutangula*
Averrhoa bilimbi	*Syzygium polyanthum*	*Musa balbisiana* var. *brachycarpa*	*Tamarindus indica*	*Moringa oleifera*

Source: Sujarwo and Caneva (2016)

Abbreviations: CFSI = cultural food significance index; UV = use value; RFC = relative frequency of citation; RI = relative importance; CVs= cultural value index

Changes in land use were observed and this was identified as a cause of the decline of *Anamirta cocculus*, *Casuarina junghuhniana*, *Garcinia dulcis*, *Garcinia parvifolia*, *Citrus maxima*, *Dacrycarpus imbricatus*, *Ficus drupacea*, *Maranta arundinacea*. Also, the fruits of some of these plants were regularly sold in the traditional market twenty years ago, but today imported fruits tend to have substituted local fruits as can now be observed in every shop (Astuti et al., 2000; Leurs, 2010; Sujarwo et al., 2016).

One of the most common approaches has been associated to the use value with questions of conservation, based on the idea that the most important species will suffer the greatest harvesting pressure (Albuquerque & Lucena, 2005; Albuquerque et al., 2006). Results from Sujarwo and Caneva (2016) could, therefore, be analyzed further and integrated into future policies regarding Balinese indigenous knowledge in relation to the cultural importance of food and nutraceutical plants, as part of the conservation of the unique cultural heritage of the island.

As regards to the cultural meanings of plant species, Garibaldi and Turner (2004) proposed the term Cultural Keystone Species (CKS) as a metaphor of the well-known concept of keystone species in ecology (Paine, 1966). According to the concept suggested by Garibaldi and Turner (2004), published roughly at the same time of a similar proposal by Cristancho and Vining (2004), CKS were identified as culturally salient species that shape the cultural identity of a group of people in a major and irreplaceable way. These species might have a role in the diet, material, and/or spiritual practices and are essential to the cultural identity and integrity of a community. Moreover, Garibaldi and Turner (2004) also introduced a quantification of this concept through an index, Identified Cultural Importance (ICI). This index is based on seven parameters, pertaining to particular facets of their cultural influence where CKSs score the highest values. Even though quantitative assessments of biocultural diversity were suggested (Harmon & Loh, 2004; Loh & Harmon, 2005), its numerical evaluation using the concept of a biocultural trait (defined as a cultural trait related to biocultural diversity) has not formally been applied to TEK yet. Sujarwo and Caneva (2016) used an approach based on the Fuzzy Set Theory (Zadeh, 1965) since it allows to deal with the complexity of TEK (Berkes, 2008). As such, the main goal of this study was to use groups of

species as biocultural traits, defining them via the Fuzzy Set Theory, and to combine the concepts of biocultural traits and cultural keystone species. The ethnobotanical data from the *aga* ethnicity in Bali were used to test this combined approach in order to describe its biocultural system.

The evaluation of the fuzzy score of the ICI index, which indicated the degree of belonging of a species to a keystone species set, allowed the identification of two subsets of species: Culturally Prominent Species (CPS) (with a degree of belonging > .85) and Culturally Unimportant Species (CUS), weakly linked to the keystone species set (with a degree of belonging < .50). Five CPSs and nine CUSs were found. It was easy to recognize that CPSs reached the maximum values very often, while CUSs always showed low values, as expected. Among the CPSs, the most important were *Arenga pinnata*, *Artocarpus heterophyllus*, *Averrhoa bilimbi*, *Cinnamomum burmanni*, and *Colocasia esculenta*. Following the definition provided in Garibaldi and Turner (2004), *Arenga pinnata* can be considered a CKS because it showed the maximal fuzzy score. The CUSs include *Elsholtzia pubescens*, *Flacourtia inermis*, *Gossypium herbaceum*, *Ipomoea pescaprae*, *Livistona rotundifolia*, *Picrasma javanica*, *Pneumatopteris callosa*, *Sarcostemma esculentum*, and *Travesia sundaica*. The other species showed an intermediate cultural importance.

Certain authors expressed some criticism about the CKS concept due to the potential reductionist approach when using single species (Platten & Henfrey, 2009), or due to its attribution through an expert-based approach (Sousa, 2014; da Silva et al., 2016). The data from Sujarwo et al. (2019), however, confirmed its usefulness to numerically express the cultural importance of species belonging to an ethnoflora or its subset. The ICI index confirmed to be a useful and synthetic way to manage and integrate information about culturally salient elements. The application of the

ICI index for the whole set of species was useful not only to compile a preliminary list where to find CKSs (Garibaldi, 2009), but also allowed us to identify some species on the basis of their biocultural importance. Through such index, the '*biocultural signature*' of a species, i.e., the set of cultural elements related to the species, can be calculated summarizing the weights of the seven parameters of the index and it can be easily showed by a diagram.

The use of only a subset of the ethno-flora of the Bali ethnicity to identify its biocultural traits resulted in a not highly limiting factor since several culturally prominent species were found and one of these could be considered a CKS. It could mean that a single subset of species, used for a specific purpose, can still convey some information about the biocultural system.

Sujarwo et al. (2019) showed that groups of species, which had a similar distribution pattern in the Bali *aga* ethnicity, could be considered as biocultural traits. TEK fitted with the concept of cultural traits representing a cumulative body of knowledge and beliefs, handed down through generations by cultural transmission, about the relationship of living beings, including humans, with one another and with their environment (Berkes, 1993). The different species could be spread within an area in different ways, along with the information about their use within or relationship with the native culture. Since the importance of a biocultural trait was directly related to its representativeness in terms of cultural influence, the use of the ICI index for a bio-cultural trait allowed us to describe the cultural influence of each group of species. This description can be useful to analyze the relationships between different biocultural traits and the gradient of variation of their cultural influence. Finally, the usefulness of such approach was related to the fact that the similarities among biocultural traits identify the main

trajectory of groups of species in the biocultural system. The network based on the edges between pair of elements revealed the best path to link biocultural traits according to their similar distribution and frequency in local communities.

The results on the cultural importance of the ethnobotanical species fitted with the data of the previous work by Sujarwo and Caneva (2016). The biocultural importance of a species became easily recognizable in comparison with a previous study (Caneva et al., 2017). Caneva et al. (2017) found that villages in the *aga* ethnicity in Bali could be considered as local networks of homogeneous ethnobotanical knowledge (i.e., the same TEK is shared among people), and the pattern of groups of species showed a heterogeneous distribution among villages. Hence, the groups of species might represent cultural units spreading in characteristic ways within an ethnicity, expressing a biocultural trait. As the use of species and species groups as environmental indicators had a rich history and tradition in vegetation ecology since the early 1900s (Clements, 1928), analogously, in this context, groups of species can be considered as state indicators of biocultural systems regarding TEK.

G. Efforts to Avoiding Cultural Erosion

In some Bali's traditional villages, traditional cultural practices and values have been supplanted. The local population is now roughly divided between the younger generation, who cater to tourism, and the older generation, whose values and knowledge seem out of step with life in the region (Sujarwo et al., 2014). Traditional ethnobotanical knowledge (TEK) has little survival value in the increasingly commercialized and market-based economy of such areas. Sujarwo et al. (2014) suggested a serious impact of modernization on Balinese TEK. Although their analyses concentrated only on

food plants, it may be indicative of a more general loss of ethno-botanical knowledge. This cultural erosion might be mitigated with appropriate cultural programs. Continued use and promotion of the Balinese life philosophy, the *Tri Hita Karana*, could lead locals to effectively conserve traditional knowledge and utilize the abundant natural resources of Bali. Continued access to youth associations, *adat* (customary) law, and good communication between the older and younger generations will very likely encourage locals to conserve traditional knowledge of plant uses. The *Tri Hita Karana* concept encapsulates this spiritual basis of Balinese knowledge of dealing with the environment to be respectful toward nature and use its resources sustainably. Observations and interviews with a wide variety of community members in all 13 of Bali's ancient villages indicated that most people still apply the principle in their daily doings, as manifested in the system of mutual help known as *saling metulung* or *gotong royong* (Sujarwo et al., 2014). Teaching the younger generation regarding the cultural traditions must be highly prioritized. Outside school, there are various private initiatives creating opportunities to learn dances and other material and performance arts. Biology classes should teach students about the conservation of biodiversity and the application of plants for food, or other purposes. As some local Balinese correctly noted, here is yet another paradox in the conservation of the Balinese culture, i.e., the school system certainly provides a cogent means to spread Balinese knowledge, beliefs and practices, but it is modeled on the Western system, supplementing the contemporary scientific approach with an anthropocentric vision. Hence, it contradicts the Balinese vision in which humans are an integrated part of the whole cosmos. The *Tri Hita Karana* principle in the current and future community resource-management is precious because it is both familiar and logical to the Balinese people. Community

resource-management programs and initiatives should concentrate on reinforcing local institutions, including the *desa/banjar adat* (village), *subak* (irrigation system), *pura* (Balinese Hindu temple) and *seka* (youth associations), and raising understanding and knowledge of the making of artifacts. Specifically, they should stress the local knowledge and philosophy underlying Balinese practices and material and performance arts. It is believed that realizing such community resource-management will revive the *gaya* or energetic way of life, making optimal use of local potential and resources. As things stand nowadays, tradition seems to receive only tokenistic recognition from commercial interests. For example, a hotel advertisement reads, 'Keeping with these ancient customs of balancing and thanking our relationship with nature, the creator and with each other, we hope your stay will indeed be very special.'

H. Future Concept of Ethnobotany

Böhlen and Sujarwo (2020) described new opportunities to apply Artificial Intelligence to the field of ethnobotany. In particular, they described a novel approach to ethnobotany documentation that harnesses machine learning opportunities, specifically for the documentation of traditional ecological knowledge with mobile phones in emerging economies. They used a case study on Bali Island as a departure point. The project maps out machine learning approaches to documentation and responds to technology and capital gradients between research contexts in the global north and south in an attempt to capture knowledge that might otherwise not be represented. Their project's goal is to investigate the potential of Machine Learning (ML) to support existing ethnobotanical research methods and to explore new methods that ML can offer to ethnobotany. More specifically, they wanted to probe whether ubiquitous mobile media could serve as a viable data collection vector, identify

which types of ML operations could process such data, and determine what kind of insights this combination might generate. In order to get a practical understanding of the challenge, they created a test site in Central Bali, Indonesia with a rich history of ethnobotanical practices. Their study gives an overview of the project 'Return to Bali' that seeks to create a living dataset of ethnobotanically significant flora on the island of Bali and new methods. Through the new methods, the underrepresented forms of knowledge can be documented, shared, and made compatible within the logics of machine learning while considering practical approaches to benefit multiple stakeholders and preventing unintended harm.

Conceptually, the *Return to Bali*'s most difficult challenge is the question of how to represent local ecological knowledge in the first place. Many aspects of local ecological knowledge are informal and experiential, grounded in personal and community experiences and experiments collected in some cases across generations. Ethnobotany seeks to do justice to these forms of knowing while acknowledging the significance of the state of the art of botany. The Böhlen and Sujarwo's project attempted to navigate these occassionally divergent vectors with ecological knowledge sourced from several individuals in Central Bali and combined with scientific grounding in ethnobotanical research, under the influence of machine learning as a helper function.

Beyond the confines of Böhlen and Sujarwo's project, we hope that other researchers will make use of the software they have created to capture under-represented knowledge in many more contexts. It is also expected that students of machine learning will find more and more varied datasets, not recycled from the internet, with which to train their skills and strengthen their appreciation and critique of machine learning systems in the future.

Conclusion and Future Research

Vegetation is a mosaic of plant communities in a landscape (Küchler, 1967). Vegetation guarantees and safeguards the life of human being and other organisms living on earth since vegetation is the principal component of any terrestrial ecosystem. A vegetation is the product of an interaction between plants, animals, and their environment (Webb & Tracey, 1994). As vegetation forms the dominant component of an ecosystem, it is most easily identified, and can be used to define an ecosystem type (Mueller-Dombois & Ellenberg, 1974, 2016). Vegetation destruction by human activities has resulted in climate change, rising poverty and worsening health and welfare of people.

Natural vegetation or also known as wild vegetation is a mosaic of plant communities within a landscape undisturbed by human activities (Eyre, 1971; Mueller-Dombois & Ellenberg, 1974, 2016; Mueller-Dombois & Fosberg, 1998). It is in a state of harmonious relationship as the result of adaptation to its environment. Natural vegetation is not only a component of biological diversity that provides natural resources, but also plays important roles in many natural processes, including hydrology and improvement of the climate. For conservation and animal ecology, data and information on the original vegetation cover are extremely important (Eyre, 1971). It is not possible to understand the

distribution of species of both plants and animals without acquiring knowledge on natural vegetation. Natural vegetation data forms a basis and provides information to support biodiversity, conservation, and environmental education as well as ecotourism, and makes basic data and information available to decision and policymakers for management, utilization and conservation of biodiversity in favor of sustainable economic development and people welfare. They are collected and compiled not only for scientific purposes, but also for a variety of practical purposes. Ecotourism is greatly dependent on data and information on natural vegetation. Holistic understanding of natural vegetation and the interaction with the environment will enable the land-use planners, for instance, to determine the best utilization of natural resources in the context of sustainable development.

In Bali, we can find a diversity of natural vegetation types extending from swampland and dry-land on the coastal areas to the tops of the mountains with a climate ranging from wet to seasonally dry. They include (1) vegetation on saline water, consisting of monsoon littoral vegetation, and monsoon mangrove forest; (2) freshwater swamp monsoon vegetation, comprising monsoon herbaceous vegetation, freshwater monsoon swamp forest, riparian vegetation; (3) dry-land vegetation, consisting of sandy and/or rocky beach monsoon herbaceous vegetation, sandy and/or rocky coastal monsoon forest or lowland seasonal deciduous monsoon forest, lowland evergreen monsoon forest, monsoon scrub, monsoon savanna, and monsoon grassland; and (4) montane evergreen forest.

Most of the lowland natural vegetation has been converted into various land-uses including gardens, rice-fields, plantations, touristic areas, and human settlements. Currently, the remaining natural vegetation can be found mostly in areas with high elevation and should be by any means well-maintained and protected.

In the chapters on vegetation, we described existing and potential terrestrial and aquatic natural vegetation of Bali. The description is not final and should be improved and expanded through further studies. Such studies should employ quantitative approaches, covering the following aspects, (1) floristic composition and structure of all vegetation types, complemented with altitudinal, soil and climatic factors in both protected and non-protected areas; (2) floristic composition, structure, and dynamics of secondary vegetation, currently expand very rapidly and yet remain poorly investigated; (3) ethnobotany in various vegetation types; (4) long-term synecological investigation of patterns and processes in permanent plots in different vegetation types, necessary for studies of growth rate, dynamics in relation to canopy structure in both natural and manipulated experimental vegetation, ecology of succession, ecological restoration, and rehabilitation, applying principles of succession, ecology of species, including phenology, reproductive ecology, fruiting biology, seed and seedling ecology, ecophysiology, and ecology of exotic invasive species. It should be emphasized here that the Flora of Bali is to date non-existent (Girmansyah et al., 2013), yet it constitutes the critical foundation for any activities related to botany, including the studies of vegetation and ethnobotany. It should be, therefore, instituted at the earliest time possible.

In the chapter on ethnobotany, we summarized that the study of the ethnobotany of wild and semi-wild food plants as well as planting a variety of plants showed that the inhabitants of Bali also gather wild and semi-wild edible plants as food. The most frequently used are fruits, followed by leafy vegetables, and tuberous roots/rhizomes. These edible plants provide food and nutrition, such as essential amino acids, vitamins, and minerals, for local communities to stay healthy and boost immunity against diseases and infections.

If managed properly, they can be valuable sources of income for local people because of their popularity and tradability at traditional markets. The villagers rely on a huge range of both local and conventional crops as food sources. Sujarwo and Caneva (2015) indicated that the Balinese maintain the sustainability of their environment by planting many species of plants with various uses in their home gardens.

In addition to food value, more than 16% of the plants were recorded as having medicinal uses which are an important part of Bali's indigenous culture, and some plants can provide useful genes for crop improvement that could have significant consequences for global food security. However, along with economic development, multi-value resources are threatened by human activities, and the associated local knowledge erodes quickly. Therefore, the management of these resources and the preservation of biodiversity as well as of indigenous knowledge are of the utmost importance.

The use of indigenous plant species is reflected in the high level of botanical knowledge possessed by the Balinese. However, culture is as dynamic as the environment, and changes are inevitable. Consequently, being a patently plant-based culture, most of Bali's traditional knowledge will certainly be lost unless it is recorded. In order to prevent the degradation of plant resources in Bali, especially with regard to the sustainable existence of the indigenous communities, it is essential to achieve a balance between the exploitation of resources and conservation. Also, it is essential to preserve and conserve traditional Balinese architecture. It is fundamental to make this a priority in local education from elementary to high school and beyond before it is too late. The presence of many kinds of Balinese buildings and information on the plant-based materials used to build them in Bali Botanic Garden appears to be a good step towards the conservation of both plants and buildings, and ultimately, of Balinese culture.

Despite the impact of the fast-growing tourist industry and the decline of local knowledge, the Balinese who live in the study areas still depend on locally available indigenous plant species for their building materials. The cultivation of these indigenous plants is in a period of crisis, especially with regard to conservation.

Traditionally, ethnobotanical research has relied on documentation of villagers' knowledge through in-person interviews collected with time-based electronic media (audio/film/video) and/or hand-written notes that are then manually evaluated and contextualized by ethnobotanists. To date, machine learning has not been applied to ethnobotany field studies. Böhlen and Sujarwo (2020) provided the first preliminary system that integrates established practices into a novel machine learning compatible framework that supports state of the art of the plant classification. Specifically, they introduced a new way to capture local ecological knowledge in the field with mobile phones in order to prepare the data for ingestion into machine learning classification.

In closing, the natural vegetation along with the ethnobotany of Bali is more than appropriate to be declared as Natural Heritage of Bali and even the UNESCOS's World Heritage.

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Glossary

Alluvium	A sediment of silt deposited by water.
Andosol	Soils found in volcanic areas consisting of volcanic pieces of all fragments of rock ejected into the air by an erupting volcano; can also be found outside active volcanic areas; they are very fertile because they are generally quite young, can usually support intensive cropping, with areas used for wet rice.
Ash	A fragment of solidified lava, measuring of less than 4 mm across, ejected during explosive volcanic eruption.
Association	A group of plant communities characterized by two or more dominant species.
Belukar	Old secondary successional forest, dominated by pioneer trees, including most common *Macaranga* spp.
Biodiversity	The variety and variability of life on Earth and the diversity is conceived at the genetic, species, and ecosystem levels; is usually greater near the equator as the result of the warm climate and high primary productivity; and is not distributed evenly on Earth, and is richest in the tropics.
Biogeography	The study of the geographic distributions of species and ecosystems in space and through geological time.

Biome	A major regional ecological community characterized by distinctive life forms and for terrestrial biome by principal plant species best adapted to the region's physical natural environment, latitude, elevation, and terrain.
Breccia	Volcanic coarse fragments of either explosive or flow origin.
Caldera	A sunken crater at the center of a volcano, formed when the magma founders, so that the center of the volcano collapses.
Cenozoic	The most recent era of earth's history stretching approximately from 65 million years BP (Before Present) to the present day.
Conglomerate	A sedimentary rock composed of water-carried rounded stones that have been naturally bonded together.
Conservation	The planned management of natural resources so as to retain its natural balance, diversity and evolutionary change in the environment.
Continuum	A gradual or imperceptible intergradation between two or more extreme values.
Continuum concept	The concept that vegetation changes continuously and can not be classified, except arbitrarily, into discrete units, since it shows gradual response to environmental change.
Crater lake	A lake found in a crater or a caldera of an extinct volcano, as well as on the irregular surface of a lava flow.
Deciduous	Shedding leaves annually at a particular season or stage of growth.
Deciduous plant	A plant that shed its leaves annually during the unfavorable season of the year or stage of growth.

Deciduous forest	A forest whose trees shed their leaves annually during unfavorable season of the year such as drought season in the tropical region and winter in the temperate region.
Dominant	In ecology, it is pertaining to a species or a group of species having the most controlling influence on community composition and form because of its abundance, size and coverage.
Ecosystem	A community of living organisms in and their non-living components of their environment, interacting as a system. These biotic and abiotic components are linked together through nutrient cycles and energy flows.
Ecoregion	An ecologically and geographically defined region which is smaller than a bioregion, which in turn is smaller than a biogeographic realm cover relatively large areas of land or water, and contain characteristic, geographically distinct assemblages of natural communities and species. The biodiversity of flora, fauna and ecosystems that characterize an ecoregion tends to be distinct from that of other ecoregions.
Ecosystem	A community of living organisms and their physical environment interacting as an ecological system.
Endemic	Native to or restricted to a particular geographic region, such as an island or continent, due to factors such as isolation or response to soil or climatic conditions.
Ethnobotany	The study of the relationship between people and plants.
Ethnomedicine	A study or comparison of the traditional medicine based on bioactive compounds in plants and animals and practiced by various ethnic groups.
Evergreen	Bearing leaves all year round.

Evergreen plant	A plant, particularly a tree or a shrub, that has leaves all year round and sheds them more or less regularly through all seasons.
Evergreen forest	A forest made up of evergreen trees; occurs across a wide range of climatic zones, and include rainforest trees in tropical regions, coniferous trees in cold climates, eucalyptus, live oak, acacias in more temperate areas.
Flora	All plant species of a given region, habitat or geological stratum (fossil flora); a published work describing the plant species of an area.
Fluvial flatland	A flat landform produced by river actions.
Genus	A taxonomic category used in the biological classification of living and fossil organisms, as well as viruses; in the hierarchy of taxonomic classification, genus comes above species and below family; plural general.
Geological formation	An aggregation of related rock layers, separated from each other by surfaces of easy separation called bedding planes.
Geomorphology	The science concerned with understanding the form of the Earth's land surface and the process by which it is shaped, both at the present day as well as in the past.
Glacial	Concerning geological intervals characterized by cold climatic condition and advancing ice sheets and caps.
Gondwanaland	The southern supercontinent which is a continuous land surface formed in the Mesozoic (about 150 million years Before Present), comprising the present South America, Africa, Arabia, Australia, Antarctica, India and New Zealand.

Grumusol	A black soil with low organic content and low fertility, rich in calcium and magnesium, originated from weathering limestone and volcanic tuff; containing more than 30% clay, sticky and swell when wet and shrink, hard and cracks when dry.
Habitat	The locality, site and particular type of local environment in which an organism can live and which can provide favorable conditions to survive.
Holistic	Pertaining to the principle that a part is understandable only in its relationship to the whole; in ecology, it is applied to studies which aim to understand ecosystems as a whole instead of investigating their component parts.
Hydrology	The science that studies water on and beneath the surface of the Earth, the existence and movement of water, the physical and chemical properties of water, and the relationship with the living biological components of the environment.
Hydromorphic soil	A soil developed in an area with an excess of moisture, including swamps, tidal areas, and inundated flatlands, and such condition tends to suppress aerobic factors in soil formation.
Interglacial period	Period between glacial ages particularly of the Pleistocene epoch.
Landscape	A landscape is a diverse land area consisting of a group of interacting ecosystems that is repeated in similar form all over.
Landscape conservation	The planning and management of the scenic and biological resources in geographic and environmental system.

Latosol	A major soil type of the humid tropical region having shallow A horizon and thick B horizon of clay and sand, which have a relatively high content of iron and aluminium oxides, giving it a red or yellow color throughout. The soil generally contains a thin but very fertile layer of humus.
Laurasia	The northern supercontinent formed by the breakup of Pangaea in the Mesozoic about 150 million years BP and comprising North America, Greenland, Europe and Asia, excluding India.
Lava	Molten rock which has flowed on earth's surface from fracture in the earth's outer crust.
Levee	Dike, embankment or flood bank which is a raised bank of alluvium flanking a river and the bank is formed when the river dump much of the load during flooding.
Lifeform	The structure, form, habits and life history of an organism.
Lithosol	A very stony shallow azonal soil without distinct horizons and with incomplete surface layers comprising of weathered rock fragments.
Littoral	The part of a sea, lake, or river that is close to the shore; in coastal areas the littoral zone spreads from the rarely inundated high water mark to the permanently submerged shoreline areas.
Lower montane forest	A forest which occurs in the lower section of the montane region in Indonesia generally at altitude of 1,000 - 2,500 m above sea level.
Magma	Underground molten rocks which move through the earth's outer crust and harden before being exposed to the atmosphere.
Malesia	Plant geographic region comprising Brunei, Malaysia, Indonesia, Papua New Guinea, Philippines, Singapore and Timor Leste.

Mangrove	A saline swamp community on tidal mud flats in tropical coastal areas where tidal range is slight, dominated by trees and shrubs, particularly of the species of *Bruguiera*, *Rhyzophora*, and *Soneratia*.
Marls	Alluvial clay which is rich in soft calcium carbonate.
Mediterranean soil	Mediterranean soils are soils which form under a Mediterranean climate; variously called Terra Rossa (on hard limestone) and Red Mediterranean Soils.
Miocene	A geological epoch within the Tertiary period about 26–5 million years Before Present.
Miopliocene	A geological epoch covering the Miocene and Pliocene within the Tertiary period about 26–1.6 million years Before Present.
Monsoon	A seasonal climatic pattern showing an alternation a cool dry period with a hot wet period; used also of the vegetation of such climatic region.
Montane	Pertaining to mountainous regions.
Mosaic of vegetation	A pattern or image made of small regular or irregular patches of plant communities in a span of vegetation.
Natural vegetation	Also known as wild vegetation, a mosaic of plant communities within a landscape undisturbed by human activities.
Paleoclimate	Ancient climates formulated before historical records and instrumental observations, using evidence from glaciers and ice sheets, geology, sediments and tree rings.
Pangaea	The global supercontinent that was formed during the Paleozoic era, started about 450 mya (million years ago) and completed by 210 mya.

Pes-caprae formation	A herbaceous community consisting mostly of creeping herbs with stems above and below ground growing behind the beach line, dominated by *Ipomoea pes-caprae* and other creeping and deeply rooting herbs tolerant to salt water and high temperature; a pioneer community of the primary succession on the beach.
Physiognomy	The appearance characteristics of a plant community or vegetation.
Physiography	Geographic features of the earth's surface.
Phytogeography	Study of the biogeography of plants.
Phytosociology	Study of vegetation comprising the organization, interdependence, development, geographical distribution and classification of plant communities.
Plant community	A group of a variety of plant species growing in an area and the groups are occurring in a repeated fashion.
Primary succession	Concerning about a process of natural development of communities on new substrates, including volcanic ash deposits and lavas produced by volcanic eruption, virgin soils previously not inhabited by plants including soils left exposed by landslides, mud deposits and sand deposits such as sand dunes and sandy beaches.
Pumice	A very light, fine-grained and cellular rock produced when the froth of the on the surface of lava solidifies.
Pyroclastic rocks	The fragments of rocks which are thrown out by volcanic eruptions and may also include pieces of the surrounding rocks.
Quaternary	The most recent geological period of the Cenozoic era, covering the last 1.6 million years BP to present, including the Pleistocene and the Holocene.

Regosol	An azonal soil without distinct horizons comprising very weakly developed mineral soil in unconsolidated materials and are extensive in eroding lands, in particular in arid and semi-arid areas and in mountain regions.
Rendzina	The humus-rich shallow soils that are usually developed from carbonate or occasionally sulfate-rich parent materials; often found in karst and mountainous regions.
Rheophyte	A plant that lives in fast moving water current which is a harsh environment, in which few other plants can survive.
Riparian	The interface between land and a river or stream, where plant communities developed along the river margins and banks called riparian vegetation and characterized by hydrophilic plants.
Sahul shelf	Part of the Australian continent shelf, lying off the northwest coast of mainland Australia; stretching northwest from Australia under the Timor Sea towards Timor, ending at the Timor Trough; to the northeast merges into the Arafura Shelf, running north from the northern coast of Australia in the Arafura Sea to New Guinea; it was exposed as dry land when sea levels fell during the Pleistocene ice age, including the last glacial maximum about 18,000 years ago.
Savanna	A community with an open canopy, dominated by grasses mixed with trees and/or tall shrubs, where characteristically trees are widely spaced so that the tree crowns do not touch one another; the open canopy allows sufficient light to reach the ground to stimulate the growth of unbroken layer of grasses and other herbaceous plants.

Secondary succession	Concerning about a process of natural development of communities on exposed old substrates whose original plant communities have been removed by various destructive human activities.
Stratum	Pertaining to a plant community which has vertical layers, composed of different heights of plants, where the individual layers are often inhabited by different animal and plant communities.
Subalpine	Pertaining to the zone of plants in Indonesia between approximately 2,500 m above sea level and the tree line at about 4,000 m above sea level.
Subduction	The process by which crustal material is returned to upper mantle of the earth.
Substrate	The surface, sediment, or medium on which an organism grows or is attached.
Succession	The sequential gradual process of progressive change and replacement in structure and species composition of plant communities either in response to an environmental change or induced by intrinsic properties of the communities themselves.
Sundaland	Sundaland known also as the Sundaic region is a biogeographic region of South-eastern Asia comprising a larger landmass that was exposed in the last 2.6 million years during periods when sea levels were lower; includes the Malay Peninsula on the Asian mainland and the large islands of Borneo, Java, and Sumatra and their surrounding small islands.

Sunda shelf	The extension of the Southeast Asia. Major landmasses on the continental shelf include the Malay Peninsula, Sumatra, Borneo, Java, Madura, Bali and their surrounding smaller islands; comprising an area of about 1.85 million km^2; sea depths are generally less than 50 meters and over extensive areas are less than 20 meters leading to strong bottom friction and strong tidal friction; see also Sundaland.
Sustainable development	Pertaining to development that requires a balance between economic prosperity, social equity and the environment to ensure equality of life now without damaging the planet for the future.
Tectonic	Concerning the movement of the rigid plates that comprise the earth's crust, and to deformation of the crustal plates.
Terra Rosa	Italian for 'red soil' which is a well-drained, reddish, clayey to silty clayey soil with neutral pH conditions and is typical of the Mediterranean region. It is also found associated with Mediterranean climates and karst elsewhere in the world.
Tertiary	A geological period of the Cenozoic era, about 6.5–1.6 million years BP, comprising the Palaeocene, Eocene, Oligocene, Miocene and Pliocene.
Topography	All natural and man-made surface features of a geographic area.
Tree line	The line which indicates the northern, southern, or upper altitudinal limit of tree cover; known also as timber line.
Tuff	A type of volcanic ash ejected from a volcanic eruption, where following the ejection and deposition the ash is transformed into a solid rock.
Upper montane forest	A forest which occurs in the upper section of the montane region (in Indonesia generally at altitude of 2500–3300 m above sea level).

Vegetation	The total plant cover in an area consisting of a mosaic of plant communities in a landscape; a vegetation reflects the product of an interaction between plants, animals and their environment.
Vegetation type	Pertaining to the kind of vegetation which is defined by characteristic dominant species, or a common aspect of the assemblage, such as an elevation range, topography, soil, climate, or other environmental factors.
Vent hole	A rupture in a volcano that allows hot lava, volcanic ash, and gases to outflow from a magma chamber below the earth's surface.
Volcanic	Pertaining to a volcano which is a mountain having hot and liquid rock known as lava coming out from an underground magma chamber; formed by the tectonic plate movement; most volcanoes have craters at the top that discharge active materials when they are active.
Wallace's line	An imaginary line separating the zoogeographic regions of Australia and Asia, including the Asian islands, passing the Philippines and the Maluku in the north then southwest between Sulawesi and Kalimantan and down to the south between Lombok and Bali, indicating that there is a difference in species on either side of the line; applicable weakly for plants.

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NATURAL VEGETATION AND ETHNOBOTANY OF BALI

Bali Island has a vast extent of vegetation, and the Balinese have good use of this in cultural, religious, and daily access aspects. This book uncovers the study of vegetation in Bali, extending from the seaside to the mountains. Moreover, in the ethnobotanical aspect, this book presents the result of a study on how Balinese people utilize the biodiversity bestowed on them.

The first part of this book will present the research on Bali's vegetation status. After we comprehend the diversity of Bali's natural vegetation, the second part of this book shows a comprehensive directory about the use of plants among Balinese, including which part of the plants is used.

We hope that this book will be a contribution to the knowledge of Bali biodiversity's status and thus become a reference for Bali's native vegetation. Furthermore, we hope that book will be a data source on Balinese local wisdom of biodiversity utilization.

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