Ethnobotanical Study of Traditional Building Materials from the Island of Bali, Indonesia

WAWAN SUJARWO*,[1] AND ARY PRIHARDHYANTO KEIM[2]

[1]Bali Botanic Garden, Indonesian Institute of Sciences (LIPI), Candikuning Baturiti, Tabanan Bali, 82191, Indonesia
[2]Herbarium Bogoriense (Botany Division), Research Center for Biology, Cibinong Science Center, Indonesian Institute of Sciences (LIPI), Cibinong West Java, 16911, Indonesia
*Corresponding author; e-mail: wawan.sujarwo@lipi.go.id

Ethnobotanical Study of Traditional Building Materials from the Island of Bali, Indonesia. Local knowledge of plant-based building materials has long been part of Balinese tradition. In order to better understand this particular tradition, we carried out a comprehensive ethnobotanical study of 13 *aga* villages. The data were obtained through semi-structured interviews and questionnaires. Seventy-eight species of plants were identified, comprising 63 genera and 34 families, of which 46% are native to the Flora Malesiana floristic region, 20% to the Indian floristic region, and 17% to the Indochinese floristic region. Ninety-one percent were trees. The most frequently used part was the stem (88%). The main use categories reported for building materials were houses (58%), religious uses (Balinese Hindu temple; 35%), stables (5%), and barns (2%). Thirty-eight percent appeared in more than one use category. *Arenga pinnata* (Wurmb) Merr. and *Magnolia champaca* (L.) Baill. ex Pierre were the two species that possessed the highest values in the preference ranking for use value (UV) followed by *Artocarpus heterophyllus* Lam. Species richness differed substantially between villages according to their different levels of traditional knowledge preservation. 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.

Studi Etnobotani Bahan Bangunan Tradisional dari Pulau Bali, Indonesia. Pengetahuan lokal bahan bangunan berbasis kayu telah lama menjadi bagian dari tradisi orang Bali. Untuk memahami tradisi tersebut dengan lebih baik, studi etnobotani yang menyeluruh dilakukan dengan menggabungkan tiga belas desa *aga*. Data etnobotani diperoleh melalui wawancara semi-terstruktur dan kuesioner. Tujuh puluh delapan jenis tanaman yang terdiri dari 63 genera dan 34 famili telah diidentifikasi, yang mana 46% adalah tanaman asli dari Malesiana, 20% dari India, dan 17% dari Indocina. Sembilan puluh satu persen adalah jenis pohon. Bagian yang paling sering digunakan adalah kayu (88%). Kategori kegunaan utama bahan bangunan adalah hunian rumah (58%), tujuan keagamaan (Pura Hindu Bali; 35%), kandang ternak (5%), dan lumbung padi (2%). Tiga puluh delapan persen dari total tanaman yang diidentifikasi memiliki lebih dari satu kategori kegunaan. *Arenga pinnata* (Wurmb) Merr. dan *Magnolia champaca Magnolia champaca* (L.) Baill. ex Pierre adalah dua jenis tanaman yang memiliki nilai tertinggi dalam peringkat nilai guna (UV), kemudian diikuti oleh *Artocarpus heterophyllus* Lam. Kekayaan spesies berbeda secara substansial diantara desa-desa sesuai dengan tingkat pelestarian pengetahuan tradisional. Meskipun dampak dari pesatnya

[1] Received 15 September 2016; accepted 29 June 2017; published online 8 August 2017

Electronic supplementary material The online version of this article (doi:10.1007/s12231-017-9385-z) contains supplementary material, which is available to authorized users.

Economic Botany, 71(3), 2017, pp. 224–240

perkembangan industri wisata dan penurunan pengetahuan lokal, orang Bali masih tergantung pada ketersediaan jenis tanaman asli untuk bahan bangunan mereka. Budidaya tanaman asli berada dalam periode krisis, khususnya yang berkaitan dengan pelestarian.

Key Words: Austronesia, building materials, plant diversity, local knowledge, wood resources.

Introduction

Throughout the world, wild, cultivated, and naturalized plants provide a "green social security" to hundreds of millions of people, for example in the form of low-cost building materials (Cunningham 2001). The basic needs of indigenous communities are highly dependent on natural products extracted from the forest, with more than 200 species of plants being used as wood resources just in Indonesia (Abdurrahim et al. 2004; Krisdianto et al. 2013; Martawijaya et al. 1981, 1989).

Balinese traditional communities live in close proximity to natural environments that possess a rich diversity of culturally valued plant species (Agung 2005; Pringle 2004; Sujarwo and Caneva 2016). Being a predominantly Hindu population surrounded by a Muslim majority, Bali and the Balinese are of particular interest for scholars of ethnology (see Pringle 2004). Its unique and distinctive *Subak* paddy fields mean that Bali is a fascinating island to explore. Bali is part of the Flora Malesiana, a floristic region that comprises the political entities of Malaysia, Singapore, Indonesia, Brunei Darussalam, the Philippines, East Timor, and Papua New Guinea (van Steenis 1950). This floristic region is one of the most diverse in terms of both animal and plant species (Myers et al. 2000). The richness of Bali's plant diversity is matched by that of its cultural heritage (Pringle 2004; Sujarwo and Caneva 2016). In other words, Balinese ethnobotanical knowledge reflects the long history of man's intimate relationship with the environment (Sujarwo and Caneva 2015; Sujarwo et al. 2015, 2016). The people that live in this floristic region, including the Balinese, use mostly native tree species as plant-based building materials. Unfortunately, Balinese traditions have increasingly and rapidly been subject to cultural erosion, as reported by Sujarwo et al. (2014). Fortunately, Bali still possesses several well-preserved indigenous traditional villages, known as *aga*, which are defined as villages inhabited by families whose ancestors lived in Bali prior to the arrival of Majapahit Hindu refugees from Java at the end of the 15th century and in the early 16th century (Coedes 1968; Hefner 1983; Pringle 2004).

A small portion (less than 20%) of the island's vegetation is still in a well-preserved natural condition (Badan Pusat Statistik 2017). 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 building materials. From a scientific viewpoint, sustainability of this plant use should ideally be based on a knowledge of the availability of resources, the potential for species regeneration, and the rate of resource use (Gaugris and van Rooyen 2009; Lawes and Obiri 2003; Obiri et al. 2002). Since most resources in this case are used by people who live in local—and 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 buildings of the Balinese *aga* 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 implemented and how the Balinese use them. The present study aims to describe 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.

Materials and Methods

Study Area

Bali is one of the westernmost islands of the archipelago known as the Lesser Sunda Islands. Like

the other Indonesian islands, Bali has a tropical climate, with fairly equable mean year-round temperature of around 30 °C and a humidity level of about 85%. It has a rainy season from November to April and a dry season from May to October. Total annual rainfall can vary across the island from 1200 to 3700 mm. The soil is generally alluvial and dominated by latosol, regosol, and andosol soil types (Badan Pusat Statistik 2017).

Bali *aga* villages are typically composed of 2000 to 5000 inhabitants (Electronic Supplementary Material – ESM), of whom the majority are farmers. The villages are inhabited by families whose ancestors lived in Bali for many generations and have maintained ancient Hindu traditions and an economy totally based on agriculture and wild natural resources. They are regarded as the indigenous Balinese people, having inhabited the island long before the coming of the later Bali people, who are well known as Bali Majapahit (Sujarwo et al. 2015). Thirteen *aga* villages were selected and surveyed for the present study, ranging geographically from 07° 54′ to 08° 50′ S and from 114° 26′ to 115° 43′ E, with altitudes of 242–1187 m (Fig. 1). Most villages occur in the higher altitudes of the island, and they are mainly concentrated in the north and east of the island, where the touristic pressure is lower. The people that inhabit these 13 villages belong to the Bali *aga* ethnic group and maintain their traditional early Balinese Austronesian lifestyle as well as having relatively free access to natural resources according to their traditional law.

About 18% of the island is still covered by forests (lowland tropical rainforest to lower montane forest), of which 8, 10, and 0.3% are classified as primary, secondary, and anthropogenic forests, respectively. Unfortunately, significant deforestation is occurring, causing a rapid decrease in forest coverage (Badan Pusat Statistik 2017).

Data Collection

Information on the use of plant species related to traditional Balinese knowledge of building materials was obtained through semi-structured interviews (individual and group discussions) and questionnaires.

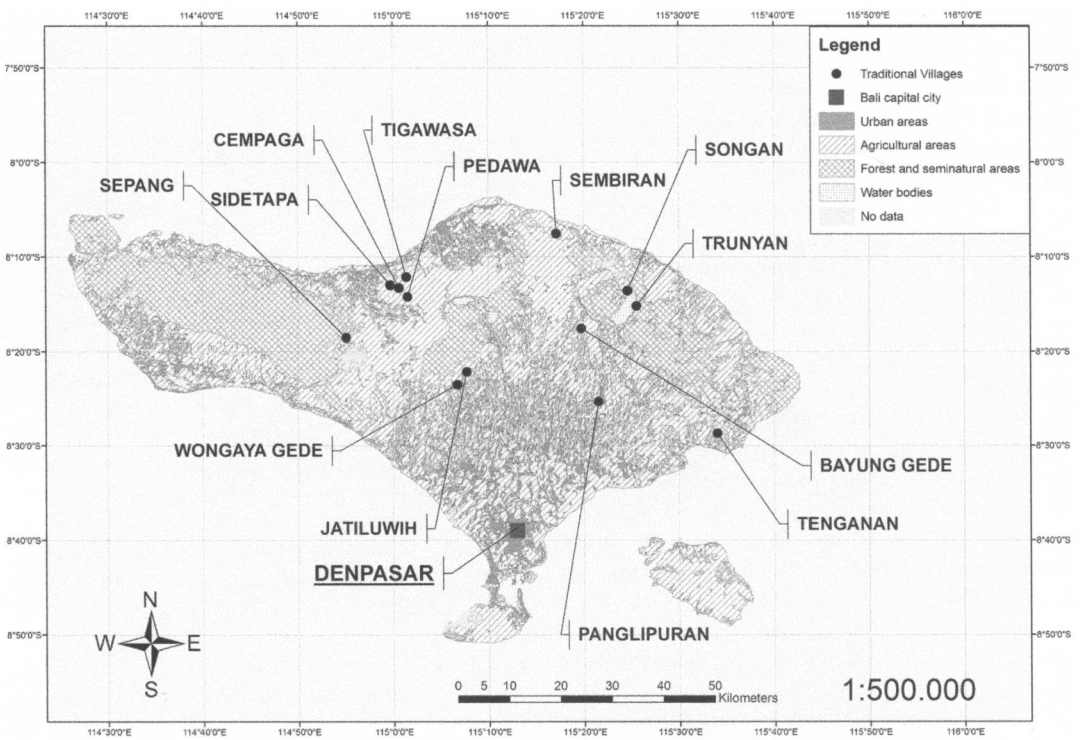

Fig. 1. The island of Bali and the location of the study area. Villages: *Bg* Bayung Gede, *Cm* Cempaga, *Jt* Jatiluwih, *Pd* Pedawa, *Pg* Penglipuran, *Sd* Sidatapa, *Sg* Songan, *Sm* Sembiran, *Sp* Sepang, *Tg* Tenganan, *Tr* Trunyan, *Tw* Tigawasa, *Wg* Wongaya Gede.

Informants were identified using the snowball method (Bernard 2002; Sujarwo et al. 2014). We selected key informants based on information obtained from the village leaders, and one additional informant was randomly selected in each village. Fifty informants were interviewed between May and July 2013. Several different kinds of interviews were carried out, including one-on-one interviews, group discussions, interviews with selected strata of informants, and structured questionnaires (Alexiades and Sheldon 1996). Before each interview, prior informed consent was requested and throughout the study, international codes of ethics were respected following Rosenthal's ethical recommendations (2006). After obtaining consent, various strata of participants (farmers, village leaders, religious leaders, and others) were interviewed, with ages ranging from 14 to 78 years old.

A minimum of four informants (three key informants and one randomly selected informant) per village were interviewed. Informants were asked to provide a list of plants (wild or semi-wild) that they used as building materials, including advanced or more detailed information such as local/vernacular names, parts of plant harvested, and for which type of buildings such parts of the plant were used. The fairly low number of women in the sample size reflects the markedly patrilineal culture of Bali (see Geertz and Geertz 1975; Pringle 2004; Swellengrebel 1969; West 2009). A detailed analysis of the factors (e.g., age, gender, and level of education) affecting differences in the traditional knowledge of plant use within the surveyed villages is provided in Sujarwo et al. (2014).

The plant specimens were collected in the form of herbarium specimens following Bridson and Forman (1992). The herbarium specimens were stored and identified in the Herbarium Hortus Botanicus Baliense (THBB) in the Bali Botanic Garden. The scientific names of plant species were verified using online sources (e.g., The Plantlist 2017), and floristic regions were obtained and applied to the present study (Takhtajan 1986).

Data provided by informants on the uses of plants as building materials were classified into four categories: (1) houses, (2) religious uses (Balinese Hindu temples or other religious shrines), (3) stables, and (4) barns (Cook 1995). Some plant species fell under more than one category. On the basis of our discussions with local inhabitants and after a review of available literature using scientific databases (such as ScienceDirect, and Google Scholar), we were able to gain a better understanding of species diversity within the areas under investigation and the sustainability of using plant-based building materials.

Data Analysis

The Use Value Index, which was first proposed by Prance et al. (1987), was employed in this present study in order to indicate "good species," i.e., the relative importance of a species to the local people and the frequency of its use. This index has been used widely in ethnobotany to indicate the most important species from the point of view of a given population (Galeano 2000; Torre-Cuadros and Islebe 2003). Species with a use value closest to 1.0 are considered a good species and widely used by the community, whereas a low use value species has a use value closer to zero and, generally, has a limited number of uses or is only used in certain areas.

The index itself is presented in a mathematical formula following Albuquerque et al. (2006), Phillips and Gentry (1993), and Tardío and Pardo-de-Santayana (2008) as follows:

$$UV = \sum Ui/N$$

Ui stands for the number of uses mentioned by each informant for a given species and N for the total number of informants.

In ethnobotanical research, the degree of practical knowledge of plant resources is usually defined as the number of species and plant uses mentioned at the time of the interview (Caneva et al. 2013; Hoffman and Gallaher 2007; Signorini et al. 2009). We used Shannon-Wiener, Margalef, and Pielou equitability indices. These indices can be applied to various subjects and are widely used in community ecology to quantify how individuals are distributed among species (Magurran 1988, 2003) and have previously been used in ethnobotanical research (Begossi 1996; Reyes-García et al. 2007; Sujarwo et al. 2014). In our context, these indices express how uses are distributed among species by capturing different aspects of knowledge diversity.

Standard statistical methods were assigned to calculate data, using statistical programs available in MS Office Excel. The Margalef index (D_{Mg}) was applied to estimate species richness (Magurran 1988, 2003) in each village.

$$D_{Mg} = \frac{(S-1)}{In(n)}$$

where S stands for the number of taxa and n for the total number of individuals.

The Shannon-Wiener index (H) was used to calculate species diversity (Magurran 1988, 2003).

$$H = -\Sigma\frac{n_i}{n}In\left(\frac{n_i}{n}\right)$$

where n_i stands for the number of taxon I and n for the total number of individuals.

The Pielou index (J) was used to calculate species evenness (Magurran 1988, 2003).

$$J = H/\ln S$$

where H stands for Shannon-Wiener index and S for the number of taxa.

Sørensen's index of similarity in percentage (Ss) was used to compare species similarity between the 13 traditional villages (Müller-Dombois and Ellenberg 1974).

$$Ss = \frac{2 \times number\ of\ common\ species}{Sa + Sb} \times 100$$

Sa stands for number of taxa in village A and Sb for number of taxa in village B.

A cluster analysis on a presence/absence matrix of species was activated in order to assess the similarity in biodiversity between villages. This analysis is essentially based on the Bray-Curtis similarity algorithm (Bray and Curtis 1957) and implemented by grouping the objects (villages) belonging to a given set (amount of villages) to define subsets (clusters in the final output of the analysis) that are as homogeneous as possible. All statistical analyses were carried out using PAST package ver. 1.94b.

Results and Discussion

Plants Used for Building Materials and their Floristic Region

The results of this present 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* (L.) Raeusch. 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 1).

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* (Wurmb) Merr.) (Fig. 2), which was used for various purposes like religious buildings (Balinese Hindu temple), houses, and stables (cowshed). As a building material, the stem of *A. 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 and Dransfield 1987). It is recorded as being one of the most important building materials in Austronesian traditional houses (Fox 2006).

Other plant material used in temple roofs were leaves from *Cocos nucifera* L. and *I. cylindrica*. However, the informants preferred fibers harvested from *A. pinnata* as the former plant's fibers were regarded as more durable than those of *I. 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 2017).

Nowadays most Balinese have replaced black fibers from *A. 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 ijukwith metal sheets can be seen as unfortunate, since a continuous use of ijuk would mean sustainable cultivation of *A. pinnata*, because the ijukcan be harvested

TABLE 1. LIST OF PLANTS USED FOR BUILDING MATERIALS AND THEIR USE VALUE.

Plant families and species (life form) [voucher specimen code]	Vernacular names	Floristic region	Part used and building type	Use value	Villages
Anacardiaceae					
Mangifera caesia Jack (tree) [WS100]	Wani	Malaysian	Stem: House	0.06	Jt
Mangifera indica L. (tree) [WS101]	Mangga, poh	Indian	Stem: Religious Use [Balinese Hindu temple], House	0.30	Bg, Pg, Sm, Tr
Mangifera odorata Griff. (tree) [WS102]	Mangga pakel	Malaysian, Indochinese	Stem: Religious Use [Balinese Hindu temple], House	0.06	Sm
Annonaceae					
Cananga odorata (Lam.) Hook.f. and Thomson (tree) [WS67]	Sandat	Malaysian	Stem: Religious Use [Balinese Hindu temple], House	0.10	Pg
Apocynaceae					
Plumeria rubra L. (tree) [WS114]	Jepun	Caribbean, Andean	Stem: Religious Use [Balinese Hindu temple]	0.06	Tg
Arecaceae					
Areca catechu L. (tree) [WS57]	Pinang	Malaysian	Stem: House	0.08	Pg
Arenga pinnata (Wurmb) Merr. (tree) [WS58]	Jaka	Malaysian, Indian	Stem: Religious Use [Balinese Hindu temple], House, Stable [Cowshed]; Black Sugar Palm Fibers: House	0.96	Cm, Jt, Pg, Sd, Sp, Tg, Wg
Cocos nucifera L. (tree) [WS69]	Kelapa	Malaysian, Fijian	Stem: House; Leaves: House	0.76	Cm, Pg, Sd, Sm, Sp, Tg, Tw
Bignoniaceae					
Mansoa alliacea (Lam.) A.H.Gentry (climber) [WS103]	Kesuna	Andean	Stem: Religious Use [Balinese Hindu temple]	0.08	Bg, Tr
Radermachera gigantea (Blume) Miq. (tree) [WS116]	Pedanten, kedanten	Malaysian, Indian, Indochinese	Stem: Religious Use [Balinese Hindu temple], House	0.04	Tr
Boraginaceae					
Cordia myxa L. (shrub) [WS70]	Kendal	Indian	Stem: House	0.10	Bg, Pg
Ehretia javanica Blume (tree) [WS76]	Blebu	Malaysian	Stem: Religious Use [Balinese Hindu temple], House	0.14	Sg, Tr
Cannabaceae					
Trema orientalis (L.) Blume (tree) [WS128]	Lenggung	Malaysian, Indian, Indochinese	Stem: House	0.10	Cm, Tr
Casuarinaceae					
Casuarina junghuhniana Miq. (tree) [WS68]	Cemara geseng	Malaysian	Stem: Religious Use [Balinese Hindu temple], House	0.22	Jt, Tr, Sg

(Continued)

Table 1 (continued)

Plant families and species (life form) [voucher specimen code]	Vernacular names	Floristic region	Part used and building type	Use value	Villages
Chrysobalanaceae					
Maranthes corymbosa Blume (tree) [WS104]	Kayu buluh	Malaysian	Stem: House	0.08	Bg, Tr
Clusiaceae					
Calophyllum soulattri Burm.f. (tree) [WS66]	Selatri	Malaysian	Stem: Religious Use [Balinese Hindu temple], House	0.06	Jt
Garcinia celebica L. (tree) [WS83]	Pradah	Malaysian	Stem: House	0.08	Jt
Garcinia parvifolia (Miq.) Miq. (tree) [WS84]	Badung	Malaysian	Stem: Religious Use [Balinese Hindu temple], House	0.04	Sd
Combretaceae					
Terminalia catappa L. (tree) [WS125]	Ketapang	Malaysian, Indian	Stem: House	0.04	Tw
Terminalia microcarpa Decne. (tree) [WS126]	Kayu kunyit	Malaysian, Northeast Australian	Stem: House	0.08	Jt, Tw
Cyatheaceae					
Cyathea contaminans (Wall. ex Hook.) Copel. (tree) [WS71]	Paku tiang	Malaysian	Stem: House	0.04	Wg
Elaeocarpaceae					
Elaeocarpus serratus L. (tree) [WS77]	Genitri	Indian	Stem: Religious Use [Balinese Hindu temple], House	0.04	Wg
Euphorbiaceae					
Aleurites moluccanus (L.) Willd. (tree) [WS54]	Tingkih	Malaysian, Indian, Indochinese	Stem: Stable [Cowshed, Pigpen]	0.06	Tg
Icacinaceae					
Platea latifolia Blume (tree) [WS113]	Udu	Malaysian, Indochinese, Indian	Stem: House	0.10	Pg, Tr
Lamiaceae					
Vitex trifolia L. (shrub) [WS129]	Lengedi			0.04	Pd
		Madagascan, Sudano-Zambezian	Stem: Religious Use [Balinese Hindu temple], House		
Lauraceae					
Lindera polyantha Boerl. (tree) [WS95]	Kayu dis	Malaysian	Stem: House	0.20	Bg, Jt, Pg, Tr
Persea americana Mill. (tree) [WS111]	Alpukat	Caribbean	Stem: House	0.06	Pg
Lecythidaceae					
Planchonia valida (Blume) Blume (tree) [WS112]	Kutat	Malaysian, Indochinese	Stem: Religious Use [Balinese Hindu temple], House	0.06	Tg
Leguminosae					
Albizia chinensis (Osbeck) Merr. (tree) [WS52]	Belalu	Malaysian, Indian	Stem: House	0.22	Cm, Tg, Tr, Tw
Albizia procera (Roxb.) Benth. (tree) [WS53]	Tingas, wangkal	Malaysian, Indian	Stem: Religious Use [Balinese Hindu temple], House	0.26	Sm, Tg, Tr, Tw

(Continued)

Table 1 (continued)

Plant families and species (life form) [voucher specimen code]	Vernacular names	Floristic region	Part used and building type	Use value	Villages
Erythrina subumbrans (Hassk.) Merr. (tree) [WS78]	Dadap	Malaysian, Indian, Indochinese	Stem: House	0.52	Bg, Cm, Pd, Pg, Sp, Tr, Wg
Falcataria moluccana (Miq.) Barneby and J.W. Grimes (tree) [WS80]	Sengon lokal	Malaysian	Stem: Religious Use [Balinese Hindu temple], House	0.12	Pd, Pg
Lythraceae					
Lagerstroemia speciosa (L.) Pers. (tree) [WS93]	Kayu tangi	Malaysian, Indian	Stem: House	0.06	Sp
Magnoliaceae					
Magnolia × *alba* (DC.) Figlar (tree) [WS97]	Base	Malaysian, Indochinese	Stem: Religious Use [Balinese Hindu temple], House	0.08	Cm, Pd
Magnolia champaca (L.) Baill. ex Pierre (tree) [WS98]	Cempaka kuning	Malaysian, Indian, Indochinese	Stem: Religious Use [Balinese Hindu temple]	0.96	Bg, Cm, Pd, Jt, Pg, Sd, Sg, Sm, Sp, Tg, Tr, Tw, Wg
Magnolia sumatrana var. glauca (Blume) Figlar and Noot. (tree) [WS99]	Kepelan	Malaysian	Stem: Religious Use [Balinese Hindu temple], House	0.08	Jt, Wg
Michelia alba DC. (tree) [WS108]	Cempaka putih	Malaysian, Indochinese	Stem: Religious Use [Balinese Hindu temple]	0.30	Jt, Pg, Tg, Wg
Malvaceae					
Hibiscus elatus Sw. (tree) [WS89]	Waru lot	Caribbean	Stem: Religious Use [Balinese Hindu temple], House	0.06	Jt
Hibiscus tilliaceus L. (tree) [WS90]	Waru	Polynesian	Stem: Religious Use [Balinese Hindu temple], House	0.08	Tg
Melochia umbellata (Houtt.) Stapf (shrub) [WS07]	Bentenu	Malaysian, Indian, Northeast Australian	Stem: Religious Use [Balinese Hindu temple], House	0.14	Pd, Pg, Wg
Pterospermum javanicum Jungh. (tree) [WS115]	Bayur	Malaysian, Indochinese	Stem: Religious Use [Balinese Hindu temple], House	0.08	Tg
Schoutenia ovata Korth. (tree) [WS120]	Kalikukun	Malaysian, Indochinese	Stem: Religious Use [Balinese Hindu temple], House	0.04	Sm
Meliaceae					
Azadirachta indica A.Juss. (tree) [WS61]	Intaran, mimba	Indian	Stem: House	0.06	Sm
Dysoxylum cyrtobotryum Miq. (tree) [WS74]	Kwanitan	Malaysian, Indochinese	Stem: Religious Use [Balinese Hindu temple], House	0.18	Jt, Tw, Wg
Dysoxylum parasiticum (Osbeck) Kosterm. (tree) [WS75]	Majagau	Malaysian	Stem: Religious Use [Balinese Hindu temple]	0.44	Jt, Pg, Sg, Sp, Tw, Wg
Melia azedarach L. (tree) [WS105]	Jempinis, mindi	Malaysian, Indian, Indochinese, Northeast Australian	Stem: Religious Use [Balinese Hindu temple], House	0.74	Bg, Jt, Pg, Sd, Sg, Sm, Sp, Wg, Tr, Tw
Sandoricum koetjape (Burm.f.) Merr. (tree) [WS117]	Sentul	Malaysian, Indochinese	Stem: House, Stable [Cowshed, Pigpen]	0.20	Cm, Pg, Sd, Tw, Wg

(Continued)

Table 1 (continued)

Plant families and species (life form) [voucher specimen code]	Vernacular names	Floristic region	Part used and building type	Use value	Villages
Toona sureni (Blume) Merr. (tree) [WS127]	Suren	Malaysian, Indochinese	Stem: Religious Use [Balinese Hindu temple], House	0.52	Cm, Pd, Sd, Sg, Sm, Sp, Tr, Tw
Lansium parasiticum (Osbeck) K.C.Sahni and Bennet (tree) [WS94]	Ceruring, langsat	Malesian	Stem: House	0.06	Pg
Moraceae					
Artocarpus elasticus Reinw. ex Blume (tree) [WS59]	Te'ep	Malaysian, Indochinese	Stem: Religious Use [Balinese Hindu temple], House	0.20	Jt, Tg, Tr
Artocarpus heterophyllus Lam. (tree) [WS60]	Nangka	Indian	Stem: Religious Use [Balinese Hindu temple]	0.92	Bg, Cm, Jt, Pg, Sd, Sg, Sm, Sp, Tg, Tr, Tw, Wg
Ficus variegata Blume (tree) [WS81]	Kayu babi	Malaysian, Indian, Fijian, Northeast Australian	Stem: House	0.06	Tr
Streblus asper Lour. (tree) [WS121]	Pali	Malaysian, Indian, Indochinese	Stem: Religious Use [Balinese Hindu temple]	0.04	Pd
Myrtaceae					
Eucalyptus alba Reinw. ex Blume (tree) [WS79]	Ampupu	Malaysian, Northeast Australian	Stem: House	0.08	Sg
Syzygium cumini (L.) Skeels (tree) [WS122]	Juwet	Indian, Indochinese	Stem: House	0.14	Cm, Sd, Tr, Tw
Syzygium polycephalum (Miq.) Merr. and L.M. Perry (tree) [WS123]	Kaliasem	Malaysian	Stem: Religious Use [Balinese Hindu temple]	0.14	Pg, Wg
Syzygium zollingerianum (Miq.) Amshoff (tree) [WS124]	Kayu batu	Malaysian	Stem: House	0.06	Jt
Oleaceae					
Fraxinus griffithii C.B. Clarke (tree) [WS82]	Nangi, angih	Malaysian, Indian, Indochinese	Stem: House	0.18	Bg, Jt, Tr
Phyllanthaceae					
Antidesma bunius (L.) Spreng. (tree) [WS56]	Buni	Malaysian, Northeast Australian	Stem: Religious Use [Balinese Hindu temple], Barn	0.06	Wg
Baccaurea racemosa (Reinw. ex Blume) Müll. Arg. (tree) [WS62]	Kepundung	Malaysian	Stem: House	0.10	Pg, Wg
Bischofia javanica Blume (tree) [WS64]	Gintungan	Malaysian, Indian, Polynesian	Stem: House, Stable [Cowshed, Pigpen]	0.10	Bg, Jt
Poaceae					
Bambusa vulgaris Schrad. (tree) [WS63]	Bambu ampel	Indochinese	Culm: House	0.04	Wg
Dendrocalamus asper (Schult.) Backer (tree) [WS73]	Bambu petung	Malaysian	Culm: House	0.28	Bg, Jt, Pd, Wg

(Continued)

Table 1 (continued)

Plant families and species (life form) [voucher specimen code]	Vernacular names	Floristic region	Part used and building type	Use value	Villages
Gigantochloa apus (Schult.) Kurz (tree) [WS85]	Bambu tali	Malaysian	Culm: Religious Use [Balinese Hindu temple], House	0.66	Bg, Cm, Jt, Pg, Sd, Sg, Sm, Sp, Tg, Tr, Tw
Gigantochloa aya Widjaja and Astuti (tree) [WS86]	Bambu jajang aya	Malaysian	Culm: House	0.10	Pg
Gigantochloa baliana Widjaja and Astuti (tree) [WS87]	Bambu bali	Malaysian	Culm: House	0.10	Pd, Tw
Gigantochloa taluh Widjaja and Astuti (tree) [WS88]	Bambu jajang taluh	Malaysian	Culm: House	0.10	Pg
Imperata cylindrica (L.) Raeusch. (grass) [WS92]	Alang-alang	Malaysian, Northeast Australian, Eastern Asiatic, Indian, Madagascan, Sudano-Zambezian	Leaves: House	0.08	Tg
Schizostachyum lima (Blanco) Merr. (tree) [WS119]	Bambu buluh	Malaysian	Culm: House	0.06	Tw
Podocarpaceae					
Dacrycarpus imbricatus (Blume) de Laub. (tree) [WS72]	Cemara pandak	Malaysian, Indochinese	Stem: House	0.16	Jt, Tr
Rubiaceae					
Breonia chinensis (Lam.) Capuron (tree) [WS65]	Jabon	Malaysian, Indian	Stem: House	0.04	Pd
Nauclea orientalis (L.) L. (tree) [WS110]	Bengkel	Malaysian, Northeast Australian	Stem: House, Barn	0.04	Wg
Hypobathrum frutescens Blume (tree) [WS91]	Kayu api	Malaysian, Indochinese	Stem: Religious Use [Balinese Hindu temple], House	0.06	Tg
Rutaceae					
Melicope glabra (Blume) T.G. Hartley (tree) [WS106]	Sampang	Malaysian	Stem: House	0.04	Jt
Murraya paniculata (L.) Jack (shrub) [WS109]	Kemuning	Malaysian, Indian, Indochinese, Northeast Australian	Stem: Religious Use [Balinese Hindu temple]	0.06	Jt
Santalaceae					
Santalum album L. (tree) [WS118]	Cendana	Indian	Stem: Religious Use [Balinese Hindu temple]	0.14	Sg, Tr
Sapindaceae					
Allophylus cobbe (L.) Raeusch. (shrub) [WS55]	Iseh	Malaysian	Stem: Stable [Cowshed, Pigpen]	0.12	Pd, Jt, Tw
Sapotaceae					
Madhuca motleyana (de Vriese) J.F. Macbr. (tree) [WS96]	Nyantuh	Malaysian	Stem: Stable [Cowshed, Pigpen]	0.06	Jt

Fig. 2. *Arenga pinnata.*

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 *A. pinnata.*

Forty-six percent of plants identified are native to the Flora Malesiana floristic region, 20% to the Indian floristic region, and 17% to the Indochinese floristic region. This considerable diversity in plant species is in accordance with and influences the cultures within the Flora Malesiana region, including that of the Balinese. The present study recorded only 14 species that are not native to the Flora Malesiana region (Table 1). The first reports of the introduction into Indonesia of plants native to the Indian region appear in the 8th century. This coincides with the introduction of Indian religious and cultural influences during the same period (Soemarwoto 1987). The presence in Indonesia of plants native to Central and South America, which were introduced by the Dutch, is first recorded in the 16th century (Simmonds 1976).

In terms of *A. 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 usages of *A. pinnata* in India is far less than in Austronesia. Rheede tot Drakenstein (1686) reported this in his *Hortus Malabaricus*, where the information regarding the usage of *A. pinnata* in Malabar, India was reported. Compare to the usage of the species by the Moluccans in Rumphius' *Herbarium Amboinense* (Rumphius 1741), the usage of the species in India is far less diverse. There is also a possibility that *A. 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 *A. pinnata* in India.

Use Value, Species Diversity, Richness, and Pattern of Similarity

The top five species with a high use value were *Magnolia champaca* (L.) Baill, *A. pinnata*, *Artocarpus heterophyllus* Lam., *C. nucifera*, and *Melia azedarach* L. Twelve species were regarded as having a medium use value, and the remaining 61 species having a low use value (Table 1). In this study, three species were identified as having a use value of nearly one. Such multi-purpose "good"species are intensively harvested by local people, which may lead to a decrease in species abundance and could even drive them to extinction. In other words, plant species might be put at risk by excessive or unsustainable harvesting practices. *M. champaca*, for example (Fig. 3), was highly targeted, leading it to suffer a decrease in abundance. It is now rare in Bali.

In addition to use value, our discussions with local people showed that three species, *A. heterophyllus*, *Dysoxylum parasiticum* (Osbeck) Kosterm., and *M. champaca* possess particularly high cultural significance. These three species are considered sacred by the Balinese, and are, therefore, well protected in numerous Balinese Hindu temples. *M. champaca* was regarded as an immensely important species by the interviewees, and within the Balinese Hindu faith, it is one of the principal flowers used in traditional offerings (Belo 1953; Brinkgreve and Stuart-Fox 1992; Hooykaas-van Leeuwen Boomkamp 1960; Hooykaas 1977; Stuart-Fox 1974), meaning that, although *M. champaca* is rarely seen, it does at least survive in temple lawns.

The results of this study showed that the villages of Jatiluwih and Penglipuran had the highest

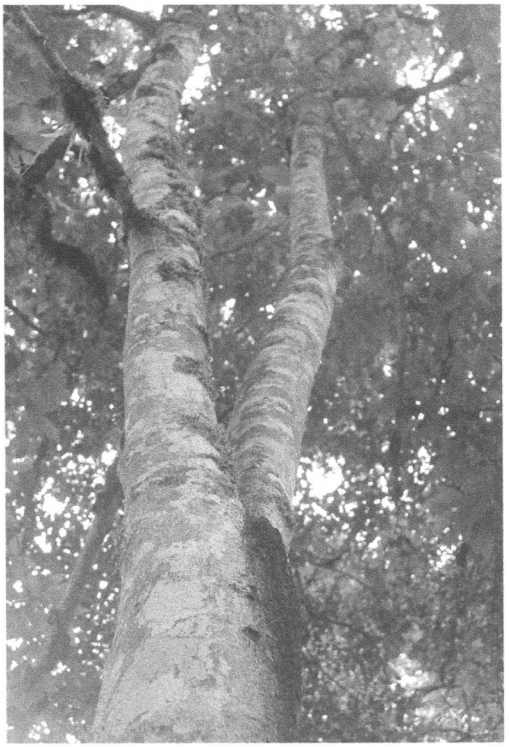

Fig. 3. *Magnolia champaca.*

number of species and of usage diversity. The villages of Sepang, Sidetapa, and Songan, on the other hand, were lowest in number of species (Table 1). The high number of plant species used in the villages of Penglipuran and Jatiluwih (25 species each) was due to the fact that a significant number of individuals made use of some cultivated plants such as bamboo (*Gigantochloa apus* (Schult.) Kurz), coconut (*C. nucifera*), jackfruit (*A. heterophyllus*), and white cedar (*M. azedarach*). This finding suggests that the plant species harvested for building materials by the Balinese were basically the same in certain villages, meaning that traditional knowledge regarding both the list of species and their use as building materials is shared by many Balinese villagers. However, such knowledge could not be applied to the entire island, since it depends on species availability and on the level of preservation of knowledge in villages.

The mean Margalef Index, which provided an understanding of species richness in the villages included in this study, varied from 2.53 to 5.37 (Table 2). The highest was recorded in Jatiluwih village and the lowest was in Sepang village. The figures in the mean Margalef Index represent an average of the total number of recorded species. Figures according to the Shannon-Wiener Plant Diversity Index varied from 2.24 to 3.19 (Table 2). The highest again was recorded in Jatiluwih village. The lowest was recorded in Cempaga village. The figures represent high mean plant diversity (Magurran 1988, 2003). The Pielou Index of species evenness showed similar values in all villages (Table 2). This result could be interpreted as indicating that traditional knowledge

TABLE 2. SPECIES RICHNESS, DIVERSITY, AND EQUITABILITY INDICES OF PLANT SPECIES USED FOR BUILDING MATERIALS IN TRADITIONAL VILLAGES OF BALI INDONESIA.

Traditional villages	Number of species	Margalef Index	Shannon-Wiener index	Pielou index
Bangli regency				
Bayung Gede	13	3.32	2.51	0.98
Penglipuran	25	5.12	3.17	0.98
Songan	10	2.57	2.29	1.00
Trunyan	23	5.05	3.10	0.99
Buleleng regency				
Cempaga	12	3.07	2.24	0.90
Pedawa	12	3.34	2.44	0.98
Sembiran	11	2.73	2.36	0.98
Sepang	10	2.53	2.26	0.98
Sidetapa	10	2.76	2.26	0.98
Tigawasa	17	4.16	2.81	0.99
Karangasem regency				
Tenganan	16	3.63	2.72	0.98
Tabanan regency				
Jatiluwih	25	5.37	3.19	0.99
Wongaya Gede	19	4.45	2.85	0.97

of some plant species exists in all villages (i.e., high equability) despite the fact that the Sørensen Index gave a wide variety of results. This means that there was a high degree of variation between different villages. The highest species similarity was observed between the villages of Cempaga and Sidatapa (73%). The lowest similarity was observed between Pedawa and Tenganan villages (7%) (Table 3).

As for the cluster analysis to assess the similarity in biodiversity between villages, villages could be grouped into two different subsets: the villages of Bayung Gede (Bg), Cempaga (Cm), Sembiran (Sm), Sepang (Sp), Sidatapa (Sd), Tenganan (Tg), Tigawasa (Tw), and Trunyan (Tr) (subset 1) and the villages of Jatiluwih (Jt), Penglipuran (Pg), and Wongaya Gede (Wg) (subset 2). The exception was the village of Pedawa (Pd) which could not be placed in any group (Fig. 4). These findings indicated that local knowledge on some plant-based building materials only exists in certain villages. For example, the knowledge of using *Breonia chinensis* (Lam.) Capuron, *Streblus asper* Lour., and *Vitex trifolia* L. as building materials can be only found in Pedawa village.

The Sustainability of Plants as Building Materials

Several species were identified by the interviewees as increasingly rare in Bali. One such species was the highly prized "cendana"or sandalwood (*Santalum album* L.). Present across a wide area from India to the Flora Malesiana 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 *S. 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 *S. album*, and at the same time, efforts have been made to protect the species in its natural habitat. *S. 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.

One of the most common issues encountered by ethnobotanists is the negative association between use value and conservation, where the species with

Table 3. Sørensen's index of similarities (in %) of species richness between traditional villages in Bali Indonesia.

	Bayung Gede	Cempaga	Jatiluwih	Pedawa	Penglipuran	Sidatapa	Songan	Sembiran	Sepang	Tenganan	Trunyan	Tigawasa	Wongaya Gede
Bayung Gede	x	32.00	42.10	24.00	42.10	34.78	34.78	41.67	43.48	20.69	55.56	26.67	31.25
Cempaga	x	x	21.62	33.33	37.84	72.73	36.36	43.48	63.63	42.86	45.71	55.17	32.26
Jatiluwih	x	x	x	16.22	32.00	28.57	34.29	22.22	34.29	29.27	37.50	38.09	40.91
Pedawa	x	x	x	x	21.62	18.18	18.18	17.39	27.27	7.14	17.14	27.59	25.81
Penglipuran	x	x	x	x	x	40.00	28.57	33.33	45.71	29.27	33.33	33.33	50.00
Sidatapa	x	x	x	x	x	x	50.00	57.14	70.00	38.46	36.36	59.25	34.48
Songan	x	x	x	x	x	x	x	47.62	60.00	23.08	48.48	44.44	27.59
Sembiran	x	x	x	x	x	x	x	x	57.14	37.04	41.18	50.00	20.00
Sepang	x	x	x	x	x	x	x	x	x	38.46	36.36	51.85	41.38
Tenganan	x	x	x	x	x	x	x	x	x	x	30.77	36.36	22.86
Trunyan	x	x	x	x	x	x	x	x	x	x	x	40.00	19.05
Tigawasa	x	x	x	x	x	x	x	x	x	x	x	x	33.33
Wongaya Gede	x	x	x	x	x	x	x	x	x	x	x	x	x

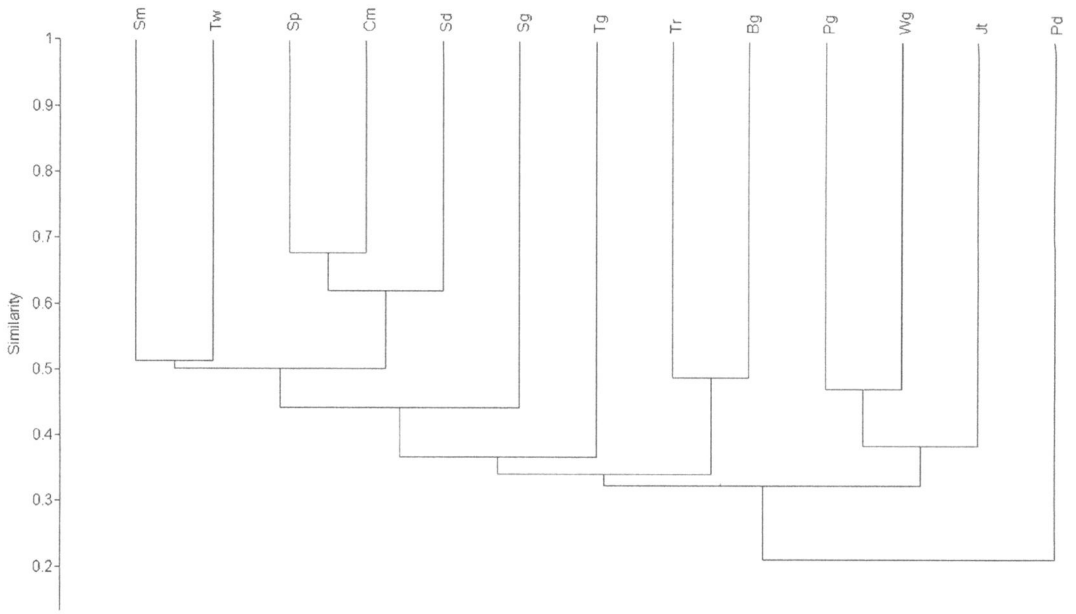

Fig. 4. Cluster analysis based on the Bray-Curtis method with villages as measurement of similarity.

the highest use value will suffer the greatest harvesting pressure (see Albuquerque et al. 2006; Kalle and Sõukand (2016); Quave and Saitta (2016)). With regard to this issue, the people of Bali have resorted to either using new species of plants or using non-plant resources. Because these new resources are unproven, they may not be as good as the original plant for their intended use (Abdurrahim et al. 2004; Krisdianto et al. 2013; Martawijaya et al. 1981, 1989).

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.

Conclusions

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 *aga* 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.

Acknowledgements

We would like to thank the Italian Ministry for Education, University, and Research (MIUR) through University Roma Tre for its financial support and Ida Bagus Ketut Arinasa, formerly director of Bali Botanic Garden, for his help in the identification of plants. We also wish to express our gratitude to the informants who took part in our study for sharing their knowledge, hospitality, and assistance. We also express our deep appreciation to Prof. Giulia Caneva of Department of Science, University Roma Tre, for sharing her valuable knowledge. Justin Bradshaw and Nigel Kerby of AVI revised the English language version. Gebby Agnessya helped in data tabulation.

Literature Cited

Abdurrahim, S., Y.I. Mandang, and U. Sutisna, eds. 2004. Atlas kayu Indonesia jilid III. Bogor: Forest Research and Development Agency the Ministry of Forestry (in Indonesian).

Agung, A.A.G. 2005. Bali endangered paradise? *Tri Hita Karana* and the conservation of the island's biocultural diversity. Leiden: Universiteit Leiden Press.

Albuquerque, U.P., R.F.P. Lucena, J.M. Monteiro, A.T.N. Florentino, and C.F.C.B.R. Almeida. 2006. Evaluating two quantitative ethnobotanical techniques. Ethnobotany Research and Applications 4: 51–60.

Alexiades, M.N. and J.W. Sheldon. 1996. Selected guidelines for ethnobotanical research: A field manual. New York: The New York Botanical Garden Press.

Aranha, J.L. 1991. A comparison of traditional settlements in Nepal and Bali. Traditional Dwellings and Settlements Review 2(2): 35–47.

Badan Pusat Statistik. 2017. Bali dalam angka 2016. Denpasar: Badan Pusat Statistik Press (in Indonesian).

Begossi, A. 1996. Use of ecological methods in ethnobotany: Diversity indices. Economic Botany 50: 280–289.

Belo, J. 1953. Bali: Temple festival. New York: Augustin.

Bernard, H.R. 2002. Research methods in anthropology: qualitative and quantitative approaches. Walnut Creek: Altamira Press.

Bray, J.R. and J.T. Curtis. 1957. An ordination of the upland forest communities of Southern Wisconsin. Ecological Monographs 27(4): 325–349.

Bridson, D. and L. Forman. 1992. The herbarium handbook (revised edition). Kew: Royal Botanic Gardens.

Brinkgreve, F. and D. J. Stuart-Fox. 1992. Offerings: The ritual art of Bali. New York: SelectBooks.

Budihardjo, E. 1985. Architectural conservation in Bali. Yogyakarta: Gadjah Mada University Press.

Caneva, G., A. Pieroni, P.M. Guarrera, eds. 2013. Etnobotanica: Conservazione di un patrimonio culturale come risorsa per uno sviluppo sostenibile. Rome: Centro Universitario Europeo per i Beni Culturali, CROMA, Università degli studi Roma Tre, Edipuglia, Bari (in Italian).

Coedes, G. 1968. The Indianized states of Southeast Asia. Hawaii: Hawaii University Press.

Cook, F.E.M. 1995. Economic botany data collection standard. Kew: Royal Botanic Gardens.

Cunningham, A. B. 2001. Applied ethnobotany: People, wild plant use and conservation. London: Earthscan.

Dransfield, J., N.W. Uhl, C.B. Asmussen, W.J. Baker, M.M. Harley, and C.E. Lewis. 2008. Genera Palmarum: The evolution and classification of palms. Kew: Kew Publication.

Fox, J.J. 2006. Comparative perspective on Austronesian houses: An introductory essay. In: Inside Austronesian houses: Perspectives on domestic design for living, eds. J.J. Fox, 1–30. Canberra: Australian National University (ANU).

Galeano, G. 2000. Forest use at the Pacific Coast of Chocó, Colombia: A quantitative approach. Economic Botany 54(3): 358–376.

Gaugris, J.Y. and M.W. van Rooyen. 2009. Evaluating patterns of wood use for building construction in Maputaland, South Africa. South African Journal of Wildlife Research 39(1): 85–96.

Geertz, C. and H. Geertz. 1975. Kinship in Bali. Chicago: Chicago University Press.

Hefner, R.W. 1983. Ritual and cultural reproduction in non-Islamic Java. American Ethnologist 10(4): 665–683.

Hoffman, B. and T. Gallaher. 2007. Importance indices in ethnobotany. Ethnobotany Research and Application 5: 201–218.

Hooykaas, C. 1977. A Balinese temple festival. The Hague: Nijhoff.

Hooykaas-van Leeuwen Boomkamp, J.H. 1960. Ritual purification of a Balinese temple. Amsterdam: North-Holland.

Kalle, R. and Sõukand, R. 2016. Current and remembered past uses of wild food plants in Saaremaa, Estonia: Changes in the context of unlearning debt. Economic Botany 70(3): 235–253.

Keim, A.P., R. Yusuf, D.D. Purwaningsih, and T. Triono. 2012. Revitalisasi aren (*Arenga pinnata* (Wurmb) Merr. (*Palmae*; *Caryoteae*) sebagai alternative bahan pemanis alami dalam rangka mendukung kemandirian gula nasional: Kajian di Provinsi Jawa Barat. In: Aren untuk pangan dan alternatif energy terbarukan, eds. M.S. Sakir, 33–46. Balikpapan: Prosiding Seminar Nasional Aren (in Indonesian).

Killmann, W., W.C. Wong, and K. Shaari. 1989. Utilization of palm stems and leaves: Annotated bibliography. Kuala Lumpur: Forest Research Institute.

Krisdianto, Barly, S. Abdurrahim, and Y.I. Mandang, eds. 2013. Atlas kayu Indonesia jilid IV. Bogor: Forest Research and Development Agency the Ministry of Forestry (in Indonesian).

Lansing, J. S. 1983. The three worlds of Bali. New York: Praeger.

Lawes, M. and I. Obiri. 2003. Using the spatial grain of regeneration to select harvestable tree species in subtropical forest. Forest Ecology and Management 184(1–3): 105–114.

Magurran, A.E. 1988. Ecological diversity and its measurement. Princeton: Princeton University Press.

———.. 2003. Measuring biological diversity. London: Blackwell Publishing.

Martawijaya, A., I. Kartasujana, K. Kadir, and P.A. Prawira. 1981. Atlas kayu Indonesia jilid I. Bogor: Forest Research and Development Agency the Ministry of Forestry (in Indonesian).

———., ———, Y. I. Mandang, and P. A. Prawira. 1989. Atlas kayu Indonesia jilid II. Bogor: Forest Research and Development Agency the Ministry of Forestry (in Indonesian).

Mogea, J.P. 1991. *Indonesia*: Palm utilization and conservation. In: Palms for human needs in Asia, eds. D. Johnson, 37–73. Rotterdam: Balkema.

———., B. Siebert, and W. Smits. 1991. Multipurpose palms: The sugar palm (*Arenga pinnata* (Wurmb) Merr.). Agroforestry Systems 13(2): 111–129.

Müller-Dombois, D. and H. Ellenberg. 1974. Aims and methods of vegetation ecology. New York: John Wiley and Sons.

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. da Fonseca, and J. Kent. 2000. Biodiversity hotspots for conservation priorities. Nature 403: 853–858.

Obiri, J., M. Lawes, and M. Mukolwe. 2002. The dynamics and sustainable use of high value tree species of the coastal Pondoland forests of the Eastern Cape Province, South Africa. Forest Ecology and Management 166(1–3): 131–148.

Phillips, O. and A.H. Gentry. 1993. The useful plants of Tambopata, Peru: I. Statistical hypothesis tests with a new quantitative technique. Economic Botany 47(1): 15–32.

Posthouwer, C., Verheijden, T.M. and van Andel, T.R. 2016. A rapid sustainability assessment of wild plant extraction on the Dutch Caribbean Island of St. Eustatius. Economic Botany 70(3): 320–331.

Prance, G.T., W. Balee, B.M. Boom, and R.L. Carneiro. 1987. Quantitative ethnobotany and the case for conservation in Amazonia. Conservation Biology 1(4): 296–310.

Pringle, R. 2004. A short history of Bali: Indonesia's Hindu realm. Singapore: Allen and Unwin.

Quave, C.L. and Saitta, A. 2016. Forty-five years later: The shifting dynamic of traditional ecological knowledge on Pantelleria Island, Italy. Economic Botany 70(4): 380–393.

Rensch, B. 1930. Eine biologische reise nach den Kleinen Sunda-Inseln. Berlin: Gebrüder Borntraeger (in German).

Reyes-García, V., N. Martí, T. Mcdade, S. Tanner, and V. Vadez. 2007. Concepts and methods in studies measuring individual ethnobotanical knowledge. Journal of Ethnobiology and Ethnomedicine 27: 182–203.

Rheede tot Drakenstein, H.A. 1686. Hortus Malabaricus. Amsterdam: Johannes van Someren, Johannes van Dyck, Hendrijk and Theodore Boom Publication (in Dutch).

Rosenthal, J.P. 2006. Politics, culture, and governance in the development of prior informed consent in indigenous communities. Current Anthropology 47(1): 119–142.

Rumphius, G. E. 1741. Herbarium Amboinense. Amsterdam: Franciscus Changuion (in Dutch).

Signorini, M.A., M. Piredda, and P. Bruschi. 2009. Plants and traditional knowledge: An ethnobotanical investigation on Monte Ortobene (Nuoro, Sardinia). Journal of Ethnobiology and Ethnomedicine 5: 6.

Simmonds, N.W., eds. 1976. Evolution of crop plants. Essex: Longman Scientific & Technical.

Soemarwoto, O. 1987 Home gardens: a traditional agroforestry system with a promising future. In: Agroforestry: A decade of development, eds. H.A. Steppler, and P.K.R. Nair, 157–170. Nairobi: ICRAF.

Stuart-Fox, D.J. 1974. The art of the Balinese offering. Yogyakarta: Yayasan Kanisius.

Sujarwo, W. 2013. Klasifikasi kelimpahan tumbuhan di Kecamatan Kintamani Bali: Studi kasus usaha konservasi. Jurnal Manusia dan Lingkungan 20(3): 276–283 (in Indonesian).

———. and G. Caneva. 2015. Ethnobotanical study of cultivated plants in home gardens of traditional villages in Bali (Indonesia). Human Ecology 43(5): 769–778.

———. and ———. 2016. Using quantitative indices to evaluate the cultural importance of food and nutraceutical plants: Comparative data from the Island of Bali (Indonesia). Journal of Cultural Heritage 18: 342–348.

———., I.B.K. Arinasa, F. Salomone, G. Caneva, S. Fattorini. 2014. Cultural erosion of Balinese indigenous knowledge of food and nutraceutical plants. Economic Botany 68(4): 426–437.

———., A.P. Keim, V. Savo, P.M. Guarrera, G. Caneva. 2015. Ethnobotanical study of *Loloh*: Traditional herbal drinks from Bali (Indonesia). Journal of Ethnopharmacology 169: 34–48.

———., ———, G. Caneva, C. Toniolo, and M. Nicoletti. 2016. Ethnobotanical uses of neem (*Azadirachta indica* A. Juss.; Meliaceae) leaves in Bali (Indonesia) and the Indian subcontinent in relation with historical background and phytochemical properties. Journal of Ethnopharmacology 189: 186–193.

Swellengrebel, J.L. 1969. Bali: Further studies in life, thought and ritual. The Hague: W. van Hoeve.

Takhtajan, A. 1986. The floristic region of the world. California: University of California Press.

Tardío, J. and M. Pardo-de-Santayana. 2008. Cultural importance indices: A comparative analysis based on the useful wild plants of Southern Cantabria (Northern Spain). Economic Botany 62(1): 24–39.

The Plantlist. 2017. The plantlist database. Royal Botanic Gardens Kew and Missouri Botanical Garden. www.theplantlist.org.

Torre-Cuadros, M.A. and G.A. Islebe. 2003. Traditional ecological knowledge and use of vegetation in southeastern Mexico: A case study from Solferino, Quintana Roo. Biodiversity and Conservation 12(12): 2455–2476.

Uhl, N. and J. Dransfield. 1987. Genera Palmarum: A classification of palms based on the work of Harold E. Moore Jr. Lawrence, Kansas: Allen Press.

Van Steenis, C.G.G.J. 1950. Flora Malesiana Vol. 1 - Ser. 1: Spermatophyta. Leiden: National Herbarium of the Netherlands.

West, B.A. 2009. Encylopedia of the people of Asia and Oceania. New York: Facts on File.