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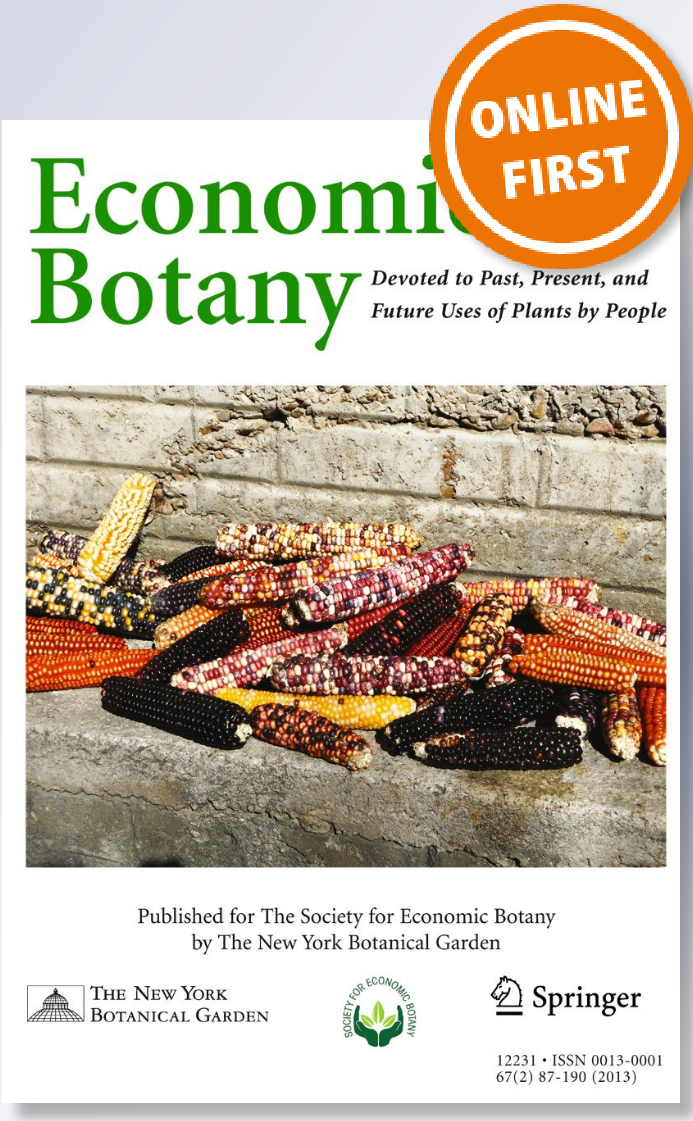

Sharing Ethnobotanical Knowledge in Traditional Villages: Evidence of Food and Nutraceutical "Core Groups" in Bali, Indonesia

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The island of Bali has several *aga* (indigenous) villages that have survived despite the pressures of an intense tourist industry and agricultural changes. A rich ethnobotanical culture persists, but the meaning of differences in traditional ethnobotanical knowledge (TEK) remains under-explored. We analyzed information obtained from interviews of inhabitants from diverse villages on food and nutraceutical plants to identify plant patterns, i.e., relevant plant groups with species sharing a similar occurrence. Through cluster analysis, we identified 12 main groups of species and found that species were grouped based on traditional knowledge and the use each community made of plants on the whole, and not on growth forms nor on specific uses. The frequency distribution of species clusters showed a bimodal trend, with several groups present only in few villages, and a few groups present in almost all villages. The latter are defined as "core groups," and represent the shared TEK of each *aga* community. Other "satellite species groups" embodied in the local TEK were related to small isolated communities. Cultural erosion caused by modernization, with the consequent fragmentation of information, was judged to be one of the main causes of increasing TEK heterogeneity.

L'isola di Bali possiede diversi villaggi indigeni (*aga*) che sopravvivono nonostante la crescente pressione legata al turismo e ai cambiamenti agricoli. A Bali ancora esiste una ricca cultura etnobotanica, ma sarebbe utile comprendere il significato delle differenze fra i villaggi relativamente alla conoscenza etnobotanica tradizionale (CET). Sono state quindi analizzate le informazioni sulle piante alimentari e nutraceutiche, al fine di identificare rilevanti gruppi di specie con riferimento a un uso tradizionale nei villaggi. Sono stati definiti dodici principali gruppi di specie sulla base della similarità ottenuta dalla cluster analysis, che sembra essere influenzata dalla conoscenza specifica di ogni villaggio, basata sulle sue tradizioni piuttosto che dalla forma biologica né dall'uso per cui le piante sono coltivate. La frequenza di distribuzione dei gruppi di specie nei villaggi è risultata bimodale, con alcuni gruppi presenti solo in pochi villaggi e pochi presenti in quasi tutti. Questi ultimi sono stati definiti "gruppi nucleari" e rappresentano la CET

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condivisa da ogni comunità *aga*. Gli altri gruppi, definiti "gruppi satellite" sono riferiti alla CET di piccole comunità locali. L'erosione colturale, con la conseguente frammentazione, è definibile come una delle cause principali di tale eterogeneità.

Key Words: Cultural erosion, fragmentation, indigenous villages, TEK, ethnobotany.

Introduction

The loss of the closely related Traditional Ethnobotanical and Ecological Knowledge (TEK hereafter, Huntington 2000; Ugulu 2011) is a worldwide problem. After its dramatic reduction in economically developed countries, TEK is now under threat in developing areas, where entire communities are rapidly changing their cultural behavior under the influence of Western models (Brosi et al. 2007; Quinlan and Quinlan 2007; Voeks 2010). Modern technologies and tourism have had a broad impact on traditional cultures, and TEK loss has been registered in all tropical areas (Benz et al. 2000; Brosi et al. 2007; Reyes-García et al. 2005), including Bali (Sujarwo et al. 2014, 2015a). At the same time, the loss of TEK is also a major threat to the conservation of biological diversity (Keller et al. 2005; Ju et al. 2013). Nowadays, the field of food and nutraceutical plants, i.e., food sources with extra health benefits, is becoming particularly important in the context of traditional plant use and has led to ongoing efforts to improve biodiversity and food security (Guarrera and Savo 2013; Heywood 2011; Tardío et al. 2006).

The island of Bali, which has several *aga* (indigenous) villages in a small area that have survived despite the pressures of an intense tourist industry and agricultural changes (Sujarwo et al. 2014), is often considered as a nucleus of ethnobotanical expertise, one that should be protected in order to conserve a relatively large amount of TEK. The people here are still considered to belong to Bali's *aga* ethnic group, having inhabited the villages for many generations. They maintain their traditional early Balinese Austronesian lifestyle, with relatively free access to natural resources according to their traditional law. They strongly uphold Hindu religious customs and traditions, which arrived in the Indonesian archipelago in the first century C.E., and remain strong, making it a kind of relic of pre-Islamic Indonesia (Pringle 2004; Supomo 2006). Outmarriage between villages occurs, except in Tenganan village, where intermarriage is prohibited (Sujarwo et al. 2014; Sujarwo and Caneva 2016). The socioeconomical tradition of Bali was originally based on the selling of agricultural products, such as green vegetables, fruit, beans, and rice (Badan Pusat Statistik 2015).

Previous studies have shown that TEK continues to provide a rich foundation for ethnomedicine, food plants, and herbal drinks (Sujarwo et al. 2015a; Sujarwo et al. 2015b), although cultural erosion seems to be an ever-increasing threat to this culture (Sujarwo et al. 2014). According to Sujarwo et al. (2014), TEK varies considerably among villages in Bali, with knowledge of plant species ranging from 28 species mentioned in the interviews in Sembiran to 55 species in Tigawasa, and with a general village median of 42 plant species. These groups of plants include native species growing in their natural habitat and semi-wild species that are sometimes managed. The factors that caused the differences were widely discussed (Sujarwo et al. 2014; Sujarwo and Caneva 2016), since the conservation of this traditional knowledge depends in part on understanding how information is shared among the villages. Considering the socioeconomic, cultural, and religious context of the situation, combined with the information we have on TEK, the questions arise: do the *aga* villages share the same core of TEK, with differences due primarily to isolation and unequal loss of information over time? Or did they arise from different ethnobotanical plant patterns among villages? In this study, we tackle this issue by analyzing ethnobotanical information on the island's food and nutraceutical plants to (i) identify the food and nutraceutical plant diversity on a local (village) scale, which gives rise to typical usage patterns; (ii) identify relationships between plants used in a large group of traditional villages, which are indicators of TEK; and (iii) evaluate how the TEK in Bali is shared among villages and within villages.

Materials and Methods

Data Set

We analyzed ethnobotanical data from 13 villages that are concentrated mainly in the northeastern part of the island, which is notably less affected by tourism compared to other parts of the island (Fig. 1).

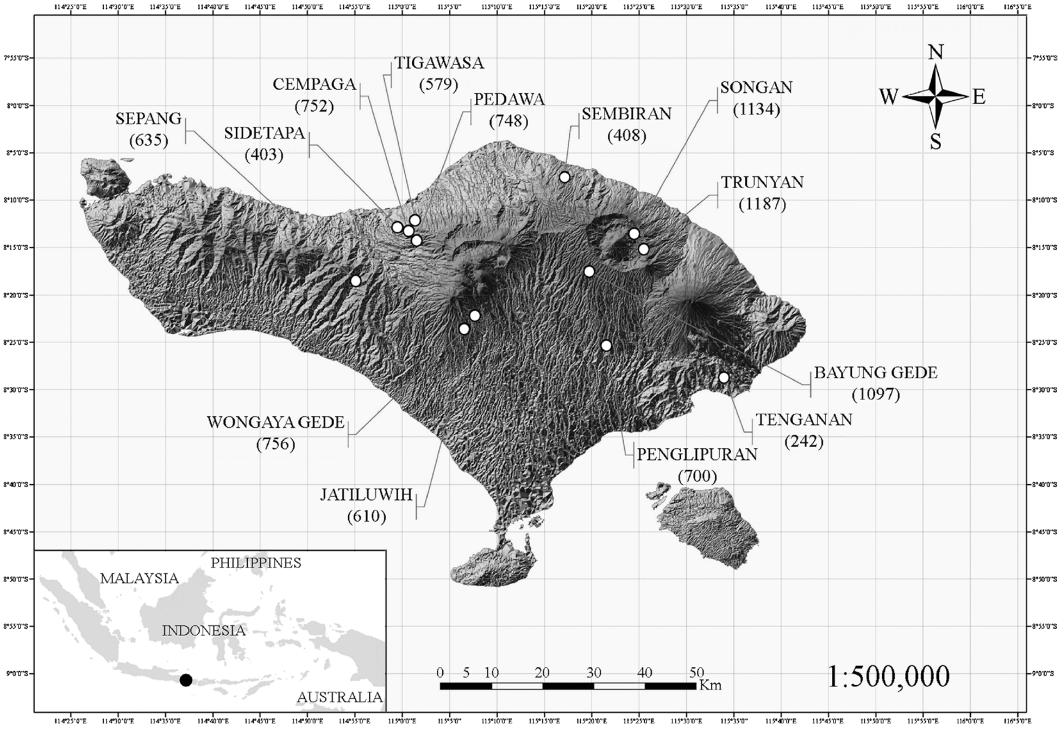

Fig. 1. The Island of Bali with the 13 studied *aga* villages.

Ethnobotanical data were collected using different interview methods (semi-structured interviews, key informant interviews, individual discussions, and focus group discussions) (Alexiades and Sheldon 1996; Sujarwo et al. 2015a), focused on wild and semi-wild plants of food and nutraceutical use and excluding only fully cultivated plants. Using a snowball sampling methodology, we selected key informants based on the information obtained from the village leaders; in addition, one informant was also selected randomly from each village. Before each interview, prior informed consent was requested and throughout the study international codes of ethics were respected following Rosenthal's ethical recommendations (2006). Following such recommendation (Alexiades and Sheldon 1996), after obtaining consent, people from various strata of society (farmers, village leaders, religious leaders, and others) were interviewed. Participants agreed to allow us to publish the identified plant names and uses.

Interviews were carried out with 50 candidates in total, including at least three from each village (generally four), with care taken to avoid interviewing closely related people.

Although attempts were made to obtain information equally from males and females (Stepp 2004; Voeks and Leony, 2004), male respondents were far more numerous than females (45 males 5 females). Males are not the main conduits of plants use traditions, but they do have a predominant role in Bali's traditional culture, especially in rural areas, while women tend to be less willing to provide information. Information was obtained from a wide age group (from 14 to 78 years of age), but most interviewees were over 45 (70%) due to the ongoing erosion of TEK among younger community members (Sujarwo et al. 2014).

Plant specimens were identified by the authors and by local botanists from the Bali Botanical Gardens. The scientific names of the plant species were verified using online sources (e.g., The Plant list 2016). Voucher specimens were deposited at the Herbarium *Hortus Botanicus Baliense* (THBB) in the Bali Botanical Gardens (Indonesian Institute of Sciences).

TABLE 1. SPECIES CLUSTERS FROM DENDROGRAM IN FIG. 1, CUTTING THE DENDROGRAM AT MINIMUM LEVEL OF SIMILARITY FUNCTION.

Group	Species	Group	Species
G1	*Gossypium herbaceum* L.	G9	*Ficus fistulosa* Reinw. ex Bl.
G2	*Gardenia jasminoides* Ellis		*Garcinia parvifolia* (Miq.) Miq
	Livistona rotundifolia (Lamk.)		*Piper cubeba* L.f.
	Lygodium circinnatum Swartz		*Psidium guajava* L.
	Travesia sundaica Miq.		*Spondias pinnata* (L.f.) Kurz
G3	*Coccinia grandis* (L.) Voigt		*Syzygium polycephalum* (Miq.) M
	Heliconia wagneriana Petersen	G10	*Alstonia scholaris* (L.) R.Br.
	Maranta arundinacea L.		*Amomum maximum* Roxb.
	Sarcostemma esculentum (L.f) R		*Andrographis paniculata* (Burm.
G4	*Bischofia javanica* Bl.		*Arenga pinnata* (Wurmb) Merr.
	Elsholtzia elata Z. & M.		*Artocarpus heterophyllus* Lmk
	Flacourtia inermis Roxb.		*Averrhoa bilimbi* L.
	Pueraria phaseoloides (Roxb.)		*Averrhoa carambola* L.
	Solanum nigrum L.		*Baccaurea racemosa* (Reinw.ex B
G5	*Areca cathecu* L.		*Celosia argentea* L.
	Artocarpus elasticus Reinw.ex		*Centella asiatica* (L.) Urb.
	Calamus reinwardtii Bl.		*Cinnamomum burmanni* Nees ex Bl
	Coleus parviflorus Bth.		*Colocasia esculenta* (L.) Schot
	Elaeocarpus sphaericus (Gaertn		*Colocasia gigantea* (Bl.) Hook.
	Euchresta horsfieldii (Lesch.)		*Costus speciosus* (Koen.) J.E.
	Momordica charantia L.		*Dioscorea alata* L.
	Morus alba L.		*Dioscorea esculenta* (Lour.) Bu
	Strobilanthes crispa Blume		*Dioscorea hispida* Dennst.
G6	*Anredera cordifolia* (Tenore) St		*Diplazium esculentum* (Retz.) S
	Cyclea barbata Miers		*Erythrina hypaphorus* Boerl.
G7	*Anamirta cocculus* (L.) W. & A.		*Hibiscus rosa-sinensis* L.
	Borassus flabelifer L.		*Lansium domesticum* Corr.
	Picrasma javanica Bl.		*Moringa oleifera* Lam.
	Zingiber zerumbet (L.) J. E. S		*Musa brachycarpa* Back.
G8	*Amorphophallus campanulatus* (R		*Ocimum basilicum* L.
	Annona squamosa L.		*Paederia scandens* (Lour.) Merr
	Antidesma bunius (L.) Spreng.		*Pangium edule* Reinw.
	Azadirachta indica A. Juss.		*Piper betle* L.
	Cicca acida (L.) Merr.		*Sauropus androgynus* (L.) Merr.
	Cucurbita moschata (Duch.) Poi		*Sida rhombifolia* L.
	Garcinia dulcis (Roxb.) Kurz		*Vernonia cinerea* (L.) Less.
	Gynura aurantiaca (Bl.) DC.	G11	*Alocasia macrorrhiza* (L.) G.Do
	Hibiscus tiliaceus L.		*Citrus amblycarpa* (Hassk.) Och
	Hydrocotyle sibthorpioides Lmk		*Curcuma purpurascens* Bl.
	Ipomoea pes-caprae (L.) R.Br		*Ficus drupacea* Thunb.
	Orthosiphon aristatus (Bl.) Mi		*Graptophyllum pictum* (L.) Grif
	Rubus alpestris Bl.		*Nicolaia speciosa* (Bl.) Horan
	Rubus calycinus Wall.ex D.Don		*Scheichera oleosa* (Lour.) Oken
	Rubus chrysophyllus Reinw.ex.		*Syzygium samarangense* (Blume)
	Rubus fraxinifolius Poir.		*Vitex trifolia* L.
	Rubus lineatus Reinw.ex Bl.	G12	*Acanthus ebracteatus* Vahl
	Rubus rosaefolius J.E. Smith		*Aleurites moluccana* (L.) Willd
	Sandoricum koetjape (Burm.f) M		*Blechnum orientale* L.
	Syzygium cumini (L.) Skeels		*Casuarina junghuhniana* Miq.
	Syzygium polyanthum (Wight) Wa		*Chrysophyllum cainito* L.
	Tamarindus indica L.		*Dendrocnide stimulans* (L.f.) Ch
	Zingiber purpureum Roxb.		*Diplazium repandum* Bl.
G9	*Amaranthus blitum* L.		*Phyllanthus niruri* L.
	Annona muricata L.		*Pneumatopteris callosa* (Blume)
	Cajanus cajan (L.) Millsp.		*Podocarpus imbricatus* Bl.
	Citrus grandis (L.) Osbeck		*Schefflera aromatica* (Blume) H
	Dolichos lablab L.		

Statistical Analyses

The matrix resulting from our data collection consisted of all species in rows and all interviews in columns. Interviews coming from the same village were grouped and the mean value was calculated. Then, we tested informant similarity using a similarity ratio function (Westhoff and van der Maarel 1978) and constructed a presence/absence data matrix (species x informants), using Analysis of similarities (ANOSIM; Clarke 1993) to verify if the similarities within villages were less than or equal to those between villages. Then, we compiled a complete dataset of the plants present in the villages by collating the information from the interviews from each village into a single group. Two matrices were obtained: matrix **A**, with 113 species and 13 villages according to the frequency of all species in each village without considering use, and matrix **B**, with 137 species uses and 13 villages according to the frequency of all species and uses. The increased number of rows in matrix B is due to the same species being sometimes used by local communities in different ways.

Statistical analyses were carried out as follows:

- Classification of species (matrix **A** data)

Clustering of species following a hierarchical approach, complete linkage method (Orloci 1978) based on similarity ratio (Westhoff and van der Maarel 1978) resemblance matrix of species. It was performed by using the Jaccard index similarity matrix.

- Ordination of species (matrix **A** data)

Ordination by principal coordinates analyses (PCoA, Gower 1966), based on the distance matrix of species obtained by transformation of similarity ratio between species (D = 1 – S; D = distance, S = similarity ratio). The same matrix was also used to ordinate species according to life-forms.

- Ordination of species with different use (matrix **B** data)

Ordination by principal coordinates analyses, PCoA, based on distance matrix of species with different use, obtained by transformation of similarity ratio between species (D = 1 – S; D = distance, S = similarity ratio).

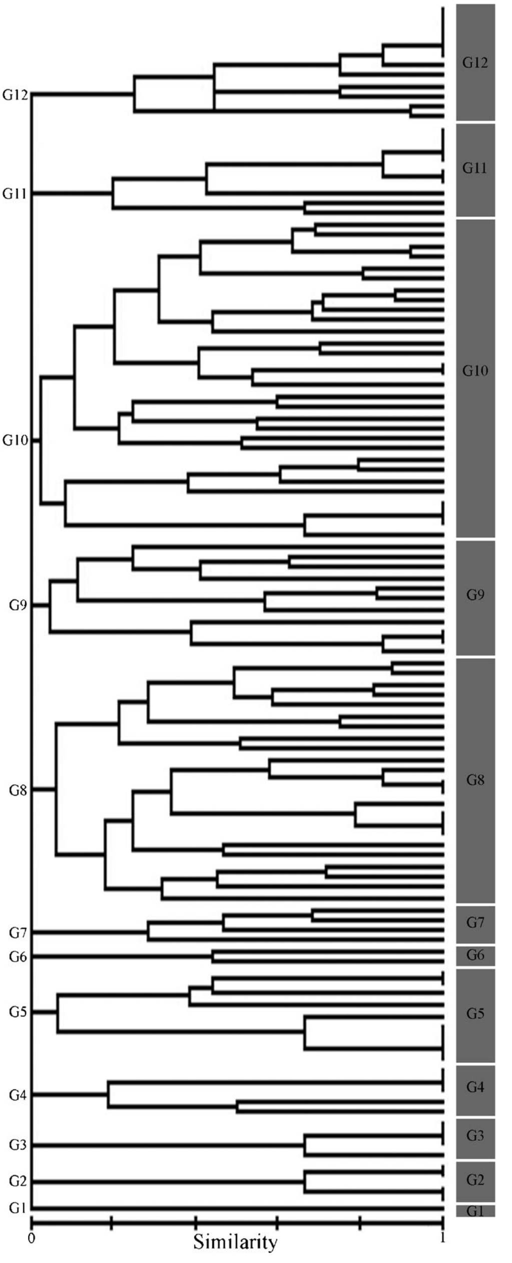

Fig. 2. Cluster tree with the complete linkage method (the species composition of the 12 groups corresponds to Table 1).

Ginkgo software (De Caceres et al. 2007) and Primer v5 (Clarke and Warwick 2001) were used for the statistical analyses (De Caceres et al. 2007).

Results

Food and Nutraceutical Plant Diversity and Typical Usage Pattern

All the traditional species used in the villages is represented by 113 taxa (Table 1), belonging to 50 families and 91 genera. The most common families are Leguminosae (6 species), Phyllanthaceae (6 species), Rosaceae (6 species), followed by Lamiaceae (5 species), Moraceae (5 species), and Zingiberaceae (5 species). The genera represented by the highest number of species are *Rubus* (6 species), followed by *Syzygium* (4 species), and *Dioscorea* (3 species). The dominant life-forms are trees (38.9%), followed by shrubs (21.2%), perennial herbs (20.4%), climbers (18.6%), and woody climbers (0.9%). Many plant parts are used, including leaves, fruits, tuberous roots, and seeds. All ethnobotanical data and the number of informants and citations for each plant are provided in Appendix 1 (Electronic Supplementary Material, ESM).

The results of interviews similarity tests (ANOSIM) were statistically significant ($R = 0.45$, $p < 0.05$), allowing rejection of the null hypothesis that the similarities within villages are smaller or equal to the similarities between villages. Thus, it could be reasonable to consider each village as a homogenous unit of TEK.

Cutting the dendrogram (obtained by a complete linkage method based on a similarity ratio from data matrix **A**) at a minimum fusion level of similarity (Fig. 2; Table 1), the typical usage pattern on a local scale was defined by 12 species groups. Group sizes varied greatly, ranging from one to 30 species, six groups included 10 species or more, and group #10 was the largest with 30 species (Fig. 2). *Colocasia esculenta* (L.) Schott, which is a native species also widely cultivated, was the only species present in every interview, and belonged to this subset. Group 1 contained only one species (*Gossypium herbaceum* L.) and group 6 included just two species (*Anredera cordifolia* (Ten.) Steenis, and *Cyclea barbata* Miers). The relative frequency of life-forms within groups is shown in Table 2. Trees dominated eight groups, followed by shrubs (two groups) and then climbers and perennial herbs dominated the remaining two groups.

Relationships Between Plants as Indicators of TEK and Its Distribution Among Villages

The relationships between plants, which were indicators of TEK, are shown by the PCoA scatter plot (Fig. 3). Some overlapping of species memberships occurred but there was also the presence of isolated clusters. Group 11 contained nine species (*Alocasia macrorrhizos* (L.) G.Don, *Citrus amblycarpa* (Hassk.) Ochse, *Curcuma purpurascens* Blume, *Ficus drupacea* Thunb., *Graptophyllum pictum* (L.) Griff., *Etlingera elatior* (Jack) R.M. Sm., *Schleichera oleosa* (Lour.) Merr., *Syzygium samarangense* (Blume) Merr. & L. M. Perry, *Vitex trifolia* L.), and was the most isolated in ordination space. The PCoA scatter plots did not show clumping of species in terms of lifeforms (Fig. 4a) and food and nutraceutical uses (Fig. 4b).

The TEK in Bali is not homogenously spread among villages, as indicated by the bimodal

Table 2. Relative frequencies of life forms of species groups in Table 1.

Group	Trees	Climbers	Perennial herbs	Shrubs	Woody climber
G1	0	0	0	*1*	0
G2	*0.5*	0.25	0	0.25	0
G3	0	0.25	*0.5*	0.25	0
G4	0.2	0.2	0.2	*0.4*	0
G5	*0.38*	0.12	0.12	0.25	0.12
G6	0	*1*	0	0	0
G7	*0.5*	0.25	0.25	0	0
G8	*0.39*	0.3	0.17	0.13	0
G9	*0.45*	0.18	0.09	0.27	0
G10	*0.37*	0.17	0.23	0.23	0
G11	*0.44*	0	0.33	0.22	0
G12	*0.5*	0	0.3	0.2	0

The values in italics correspond to the frequencies greater than 0.35, therefore considered more relevant within each group from G1 to G12

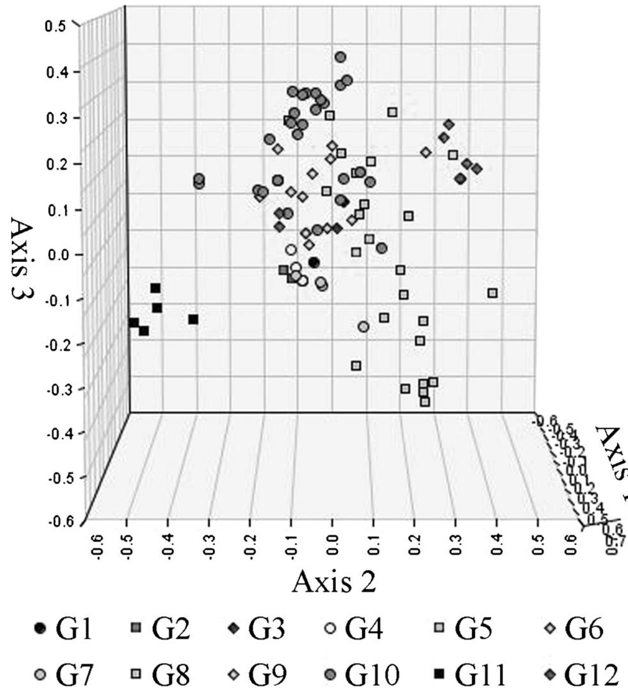

Fig. 3. Principal coordinate analysis on species groups defined in the cluster tree.

distribution of species groups (Fig. 5a): several species groups were only present in a few villages, while only three groups, those larger in size, occurred almost everywhere. It was therefore possible to define two types of species groups: the main group as a "core group," consisting of plant species present in all or most villages, representing the shared *aga* TEK, and those which represented the individual

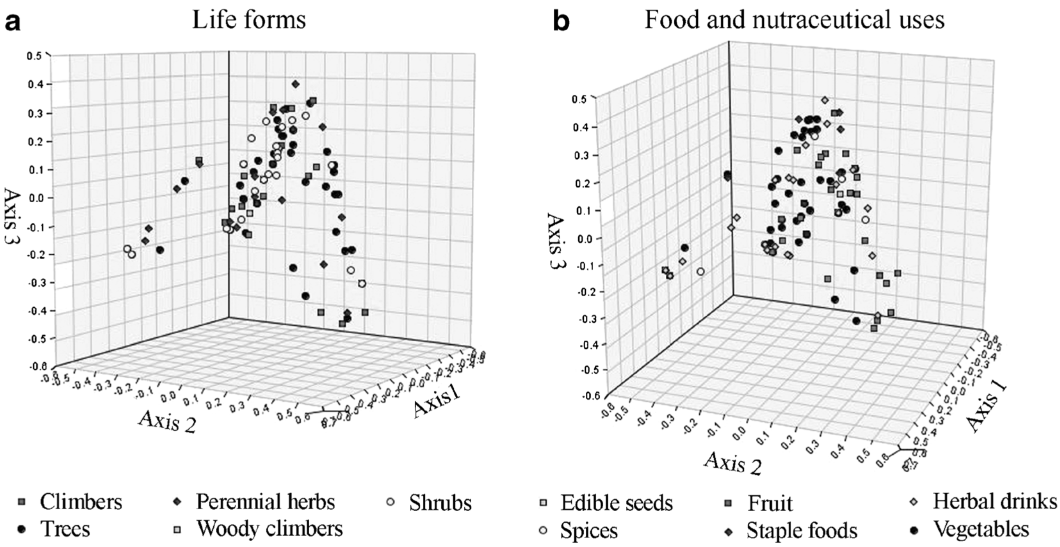

Fig. 4. Principal coordinate analysis on species grouped according to biological form (**a**) and to the way a plant is generally used by villages (**b**).

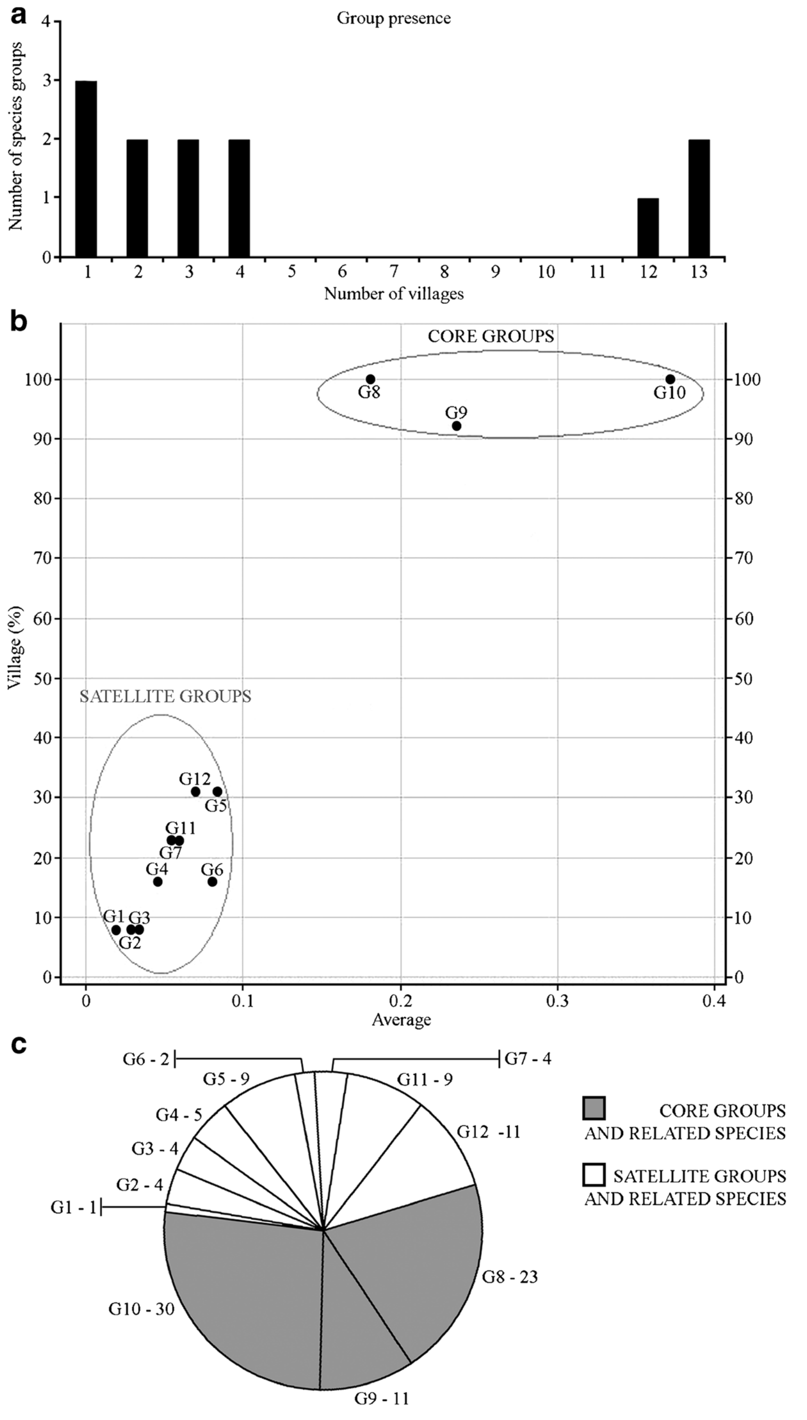

Fig. 5.. **a** Frequency distribution of the groups of species (Table 1) in the *aga* villages showing a bimodal trend. **b** Scatter plot of species groups: x axis is the average relative frequency of species belonging to a single group; y axis is the percentage of *aga* villages in which a group of species is present. **c** Pie chart of "satellite" and "core" groups (Table 1) and related species.

TEK restricted to specific villagesas "satellite groups," according to the terminology proposed by Hanski (1982) (Fig. 5a, b). The number of species belonging to core clusters (64 species) was greater than that of the satellite clusters (49 species) (Fig. 5c).

Discussion

A tradition is a belief or behavior passed down within a group or society that has symbolic meaning or special significance originating in the past (Green 1997). TEK is a product of direct human-human communication and generations of lives lived in close contact with the environment over thousands of years, and can be considered a practice as old as ancient hunter-gatherer cultures (Berkes 1993).

The clusters we identified in this study represent different pieces of ethnobotanical information detected in the *aga* ethnicity, and they represent specific ways of organizing and spreading TEK. Species similarity linked by traditional use does not depend on life-forms or on different food and nutraceutical aspects, but rather one ethnic community tradition.

The "core and satellite species hypothesis," developed by Hanski (1982), was originally used to explain species occupancy patterns across landscapes, and according to this model, which has been applied for the first time to traditional knowledge, it was possible to identify two ways of sharing and spreading ethnobotanical information. The "core TEK" consists of species groups derived from a common belief belonging to the whole ethnic group and describes shared knowledge. Core-TEK is made up of only a few species groups, but each group contains many species, around 60% of the total, making them highly relevant. Satellite-TEK, however, is associated with local knowledge limited to quite small communities (one or a few villages), the ethnobotanical information is divided into several species-groups that are composed of a small number of species.

In keeping with this metaphor, satellite TEKs seem to gravitate around the core TEK, maintaining their specific nature and following a specific "linear linkage" that depends on its characteristics. Satellite TEK enriches and gives rise to more heterogeneity in cultural traditions of a single ethnicity. However, as the average number of plant species used per village is substantially lower than the total for all villages, and the distances between villages is relatively large (Sujarwo et al. 2014), it could be assumed that their geographical/physical isolation has caused a strong fragmentation of TEK. Some satellite species, such *Gossypium herbaceum*, *Anredera cordifolia*, or *Cyclea barbata* probably never belonged to a shared TEK, but may be examples of traditions linked to a very limited number of individuals.

Even if the data set was expanded, especially including more women to make it more representative of the entire ethnic group, cultural erosion still seems to be the most prominent factor in explaining the observed heterogeneity in TEK (Sujarwo et al. 2014). Geographical, ecological, and local cultural differences, however, could also have had a role.

Conclusions

Bali *aga* ethnic groups are culturally very close and conservative, but the erosion of their traditions and their TEK is an ongoing phenomenon. This study defined a large "core group" of food and nutraceutical species used in all villages, representing the common TEK throughout all *aga* communities, and smaller "satellite groups" related to geographically isolated local communities. Data also show a high degree of TEK heterogeneity (satellite TEK). Although the group of species belonging to the core TEK shared by all villages was relatively large compared to the satellite TEK, the latter still contained around 40% of the total. The importance of this heterogeneity could be further elucidated through ethnic and sociological studies and may help preserve and safeguard TEK.

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