Review:
Persistent pioneers; *Borassus* L. and *Corypha* L. in Malesia

GRAHAM E. EAGLETON

Center for Plant Conservation, Bogor Botanic Gardens, Indonesian Institute of Sciences. Jl. Ir. H. Juanda No. 13, Bogor 16003, West Java, Indonesia. Tel./Fax.: +62-251-832217, email: graham.eagleton@gmail.com

Abstract. *Eagleton G.E. 2016. Review: Persistent Pioneers;* Borassus *L. and* Corypha *L. in Malesia. Biodiversitas 17: 716-732.* This review traces advances in taxonomic and ethnobotanic understanding of the genera *Corypha* L. and *Borassus* L. gained from research since the time of publication of "Harvest of the Palm; Ecological Change in Eastern Indonesia'' by James J. Fox in 1977. It posits testable hypotheses arising from the literature: firstly, that both genera were present in the furthest parts of island Southeast Asia prior to a definitive Indianized cultural expansion in the first millennium CE.; secondly, that two of their species "lontar" *Borassus flabellifer* L. and "gewang" *Corypha utan* Lam. were significant components of pre-agricultural economies of the archipelago, but that their full economic exploitation benefited from later cultural stimuli from the Indian subcontinent. To test these hypotheses, lines of research with potential benefits for local economies in semi-arid Indonesia are proposed.

Keywords: *Borassus*, *Corypha*, origins, proto-agricultural uses, Southeast Asia

INTRODUCTION

It is forty years since James Fox's "Harvest of the Palm" gathered together written and oral traditions concerning the pivotal role of two palm species, *Borassus flabellifer* L. and *Corypha utan* L., in certain subsistence economies of Nusa Tenggara Timur, Indonesia, and other parts of the semi-arid tropics (Fox 1977). In the intervening years, research has accumulated providing a clearer picture of the taxonomic status of the two palms and of their economic significance, past, present and potential. The purpose of this paper is to re-examine the findings of Fox (1977) in the light of this more recent research and to proffer avenues of useful new investigation.

NAMES

"Lontar" (*Borassus flabellifer* L.) and "gewang" (*Corypha utan* Lam.) are Indonesian names for two palm species concentrated mainly in the drier parts of the archipelago. In colonial India, *B. flabellifer* was known as "palmyra" and the majestic *Corypha umbraculifera* L. as "talipot".

Lontar and gewang are fan-leafed palms in contrast to feather-leafed palms like coconut and oil palm, and can be mistaken for one another at first glance. Nevertheless, they are very different in growth habit, especially reproductive biology (Figure1). Gewang is hermaphroditic (its flowers having both stamens and gynoecium) and monocarpic (the palm dies after a single spectacular flowering and fruiting season). Lontar is dioecious (staminate flowers and pistillate flowers are borne in separate inflorescences, on different plants) and pleonanthic (the palms flower

repeatedly, potentially over several seasons; not dying after flowering; Uhl and Dransfield 1987).

There are other local Indonesian names for the lontar, for example: "siwalan", "tal", "ental" and "rontal" in Java; "kori" or "koli" in Flores; "tua" in Roti; and "duwe" in Savu (Heyne 1927; Tjitrosoepoma and Pudjoarinto 1983). Of particular relevance to the question of origins, are the cognates of the Sanskrit name "tala" that are to be found in India and Sri Lanka, Java and Madura, to at least as far east as Sumbawa and Sulawesi (Burkill 1966; Fox 1977).

The close ecological association and similarities in form between *Corypha* species and the lontar gave rise to parallels in the names attributed to the two. Rumphius applied the Latin name *Lontarus silvestris* (common name 'Lontar Utan') to the gewang (see Figure1), and *Lontarus domestica* to the lontar, while recognizing their striking differences in reproductive structures (Rumphius 1741). Similarly, according to Burkill (1966), the Sanskrit word "tala" was not confined to *B. flabellifer*, but was also used to refer to *Corypha* species and even to other common Indian palms. For Sanskrit literati and later Buddhist scholars, the fact that leaves of *B. flabellifer* could substitute for the leaves of *Corypha umbraculifera* L. as the writing medium for their sacred scriptures was no doubt a significant reason for the parallelism in nomenclature.

Nevertheless, traditional taxonomies recognized clear difference between the two genera, and in the Malesian archipelago the names attached to *Corypha utan*, for example "ibus" in Aceh and North Sumatra; "gebang" in parts of Java and Bali; "pocok" in Madura; "silar" in Sulwesi; "tula" in Roti; and "buri" in parts of the Philippines, suggest negligible reference to Indianized influences (Heyne 1927; Burkill 1966).
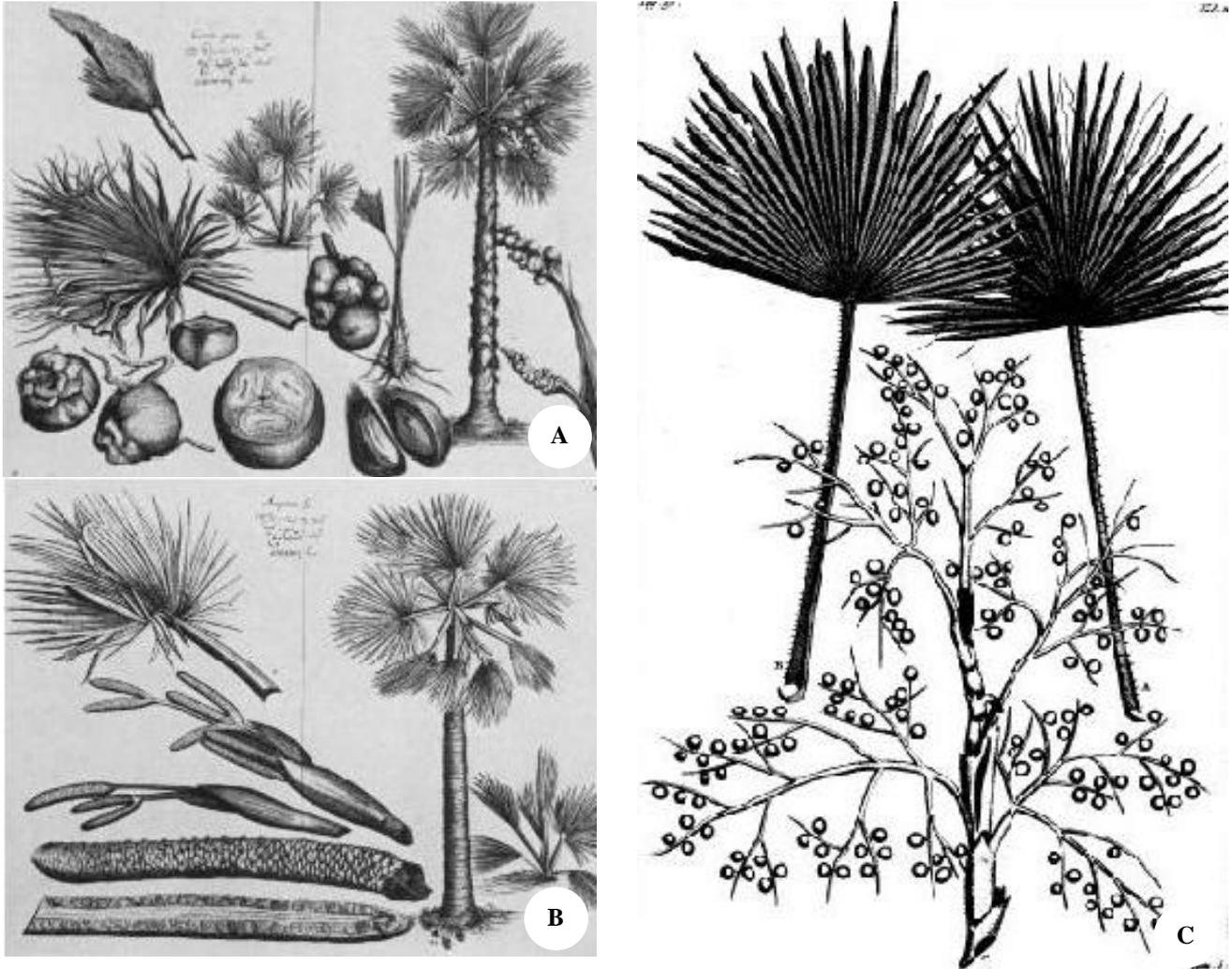
Figure 1. Early records. **A.** The lectotype for *Borassus flabellifer* L.   The pistillate form   *Ampana*; Rheede (1678-1703), Hortus Indicus Malabaricus 1:13-14, *pl.*10. **B.** The staminate form   *Carimpana*; Rheede (1678-1703), Hortus Indicus Malabaricus 1: 11-12, *pl.* 9. **C.** The lectotype for *Corypha utan* Lam. *Lontarus silvestris*; Rumphius (1741), Herbarium Amboinense 1: 53-56, *pl.* 11

TAXONOMY

Borassus L.

Up until Beccari's revision of the genus *Borassus* in 1914 and more substantially in Beccari (1924; published after his death), the consensus had been that the genus in Asia was represented by a single widely distributed species, *B. flabellifer,* described by Rheede tot Drakenstein (1678) (see Figure 1) and by others in the seventeenth century and recognized as a distinct species by Linnaeus (1753). In Beccari (1924), the distinction first drawn by Martius (1838) between the Asian *B. flabellifer* and African members of the genus was elaborated. In addition, two new species were defined for the Asian region; namely *B. heineanus* Becc., from the northern coastal regions of the island of New Guinea, and *B. sundaicus* Becc., located by Beccari in the Indonesian archipelago. Subsequently, *B. heineanus* was accepted as a separate species by other botanists in the field. However, the distinction drawn by Beccari (and later supported by Fox 1977) between *B.*

flabellifer and *B. sundaicus* did not gain wide acceptance (see for example Heyne 1927; Burkill 1966). More detailed anatomical observation of a much wider sampling in Indonesia than was available to Beccari, removed support for the concept of lontar as a separate, Indonesian, species of *Borassus* (Pudjoarinto 1982; Sastrapradja and Davis 1983; Tjitrosoepomo and Pudjoarinto 1983).

In recent times, advances in molecular identification have provided a more secure basis for the classification of flowering plants (APG IV 2016), including the Arecaceae in particular (Asmussen and Chase 2001; Bayton 2005; Dransfield et al. 2005; Asmussen et al. 2006; Dransfield et al. 2008). Based on these new insights, Bayton (2007) has revised the taxonomy of *Borassus* L., the first comprehensive review of the genus since Beccari (1924). He recognizes five species in contrast to Beccari's seven: they are, from east to west in distribution, *B. heineanus* Becc.; *B. flabellifer* L.; *B. madagascariensis* (Jum. & Perrier) Bojer ex Jum. & Perrier; *B. aethiopum* Mart.; and *B. akeassii* Bayton, Ouedraogo & Guinko.

Borassus heineanus Becc. is enigmatic. Nuclear and chloroplast DNA sequencing (Bayton 2005) indicate that *Borassus* including *B. heineanus* is "monophyletic in its current circumscription", nevertheless this New Guinea species resembles members of the genus *Borassodendron* Becc. in its ecology and several morphological features. Knowledge of *B. heineanus* (based on limited data from seven locations in the coastal hinterland of northern New Guinea) indicates a tropical rainforest adaptation in contrast to the semi-arid savannah adaptation of the other *Borassus* species. In keeping with this tropical forest adaptation is the dorsi-ventral differentiation of the tissue layers in the leaf lamina (which it shares with *Borassodendron* species and most other palm species of the moist tropics) in contrast to the iso-lateral leaf anatomy of the other *Borassus* species adapted to the semi-arid tropics (Tomlinson 1961; Bayton 2007; Horn et al. 2009; Tomlinson et al. 2011). Other morphological characteristics which *B. heineanus* shares with *Borassodendron* include unarmed petioles with a comparatively high length to width ratio (Dransfield 1972; Bayton 2007); staminate inflorescences in the male plants that branch to one order only; and in the fruit of the female palms, pyrenes that are longer than they are wide and with internal flanges perpendicular to the main endocarp walls. Nevertheless, in several other respects ─ for example, in its pollen morphology (Ferguson et al. 1986), its costapalmate leaf lamina and most importantly its molecular characteristics (Bayton 2005) ─ *B. heineanus* resembles other members of *Borassus* rather than *Borassodendron*.

Geographically, the member of *Borassus* most closely connected with *B. heineanus* is *B. flabellifer.* It is to this latter species that the lontar belongs. Outliers for *B. flabellifer* are found in Southern China and the Western side of the Arabian Gulf but it is likely that these palms are not part of the species' natural distribution but are the result of dispersion by humans. The manifest material benefits from all species of the genus have led to their utilization across the full range of its distribution. Indeed, the morphological resemblances as well as similarities in the way different human societies have used the palms led early authors to group the African and Asian members under the single species label, *B. flabellifer.* It was only after reviews of the genus, by Beccari (1914) and later on by Kovoor and Hussein (1983), Dransfield and Beentje (1995), Ake Assi and Guinko (1996) and Bayton et al. (2006), that the African populations of the genus were considered sufficiently distinct to justify separate species status for the three African species recognized in Bayton's (2007) recent review; namely, *B. aethiopum* throughout much of equatorial Africa, *B. madagascariensis* confined to Madagascar, and *B. akeassii* in West Africa.

Corypha L.

As for *Borassus*, the genus *Corypha* straddles the Wallace line with a distribution stretching from Southern India to Northern Australia. But unlike the case for *Borassus*, there are no African species of *Corypha*, and though greatly influenced by human usage, the distribution for *Corypha* clearly reflects an underlying natural distribution. Beccari (1933) recognized eight species in his posthumously published review of the genus, but most recent authors maintain no more than six.

The gewang, *Corypha utan* Lam., has been variously named in its different locations. Fox (1977) used *C. elata* Roxb., following early authors in India; other synonyms include *C. gebang* Mart., *C. gembanga* (Blume) Blume, *C. griffithiana* Becc., and *C. macropoda* Kurz ex Linden. However, in most modern treatments, *C. utan* has been accepted as a single species dispersed from southern India, the Andaman Islands and the Myanmar/Thai peninsular through to Southern New Guinea and Arnhem Land and Cape York in Northern Australia (Henderson 2009; Dowe 2010).

A striking member of the genus, the "talipot" of Southern India and Sri Lanka, *Corypha umbraculifera* L., can readily be distinguished from *C. utan* (Roxburgh 1832); the base of the leaf petiole in *C. umbraculifera* has a very distinct pair of auricles on the outer edge (Griffith 1850) that is not present in *C. utan.* Moreover, the petioles of *C. utan* (synonym *C. elata*) are much narrower than in the talipot and armed with teeth that are much larger. Roxburgh (1832) observed that *C. utan* has flowers with stamens longer than the petals, and an inflorescence that is more compact in structure than that of *C. umbraculifera.* This was confirmed in careful observations by Douglas and Bimantoro (1957) at Bogor Botanic Gardens. For all *Corypha* species, what appears to be a single enormous, pyramidal inflorescence atop the crown of leaves at the final phase of life is a structure of "*separate inflorescences ... each one emerging from the axil of a reduced leaf*" (Henderson 2009). Douglas and Bimantoro (1957) confirmed Beccari's observation that in *C. umbraculifera* the primary inflorescence branches split through the subtending leaf sheaths, in contrast to the inflorescences of *C. utan* (synonym *C. elata*) that emerge from the mouths of the leaf sheaths.

The genus as a whole is in need of revision. *Corypha taliera* Roxb., which shares some of the characteristics of *C. umbraculifera* (e.g. auricles at the base of the leaf petioles, and inflorescences piercing the subtending leaf sheaths), was nevertheless considered a distinct species by Roxburgh (1820). Its separate species status has been maintained by subsequent authors. Recorded in the nineteenth century as being endemic to the Bay of Bengal, the species is currently listed on the IUCN Red List as extinct in the wild and in recent decades appears only to have been recorded in cultivated garden settings in India (Indian Botanic Garden, Kolkata), USA (Fairchild Tropical Garden, Florida) and perhaps Bangladesh (IUCN 2016). Another species, *Corypha microclada* Becc., is listed as vulnerable (IUCN 2016) and has only ever been recorded from the small island of Biliran in the Philippines. It remains to be seen whether separate species status for the Biliran populations can be maintained, given the widespread distribution of *C. utan* in the Philippines.

On the other hand, the species *Corypha lecomtei* Becc. ex Lecomte is extant in the wild and quite distinct from *C. utan* (Lecomtei 1917; Rukan and Suwanwaree 2010; Rukan et al. 2010) despite sharing with it narrow, non-

auricular petioles and having inflorescences that emerge from rather than breaking through the subtending leaf sheaths (Henderson 2009). The petioles have distinctive margins with much finer armament than *C. utan*. The maximum height of *C. lecomtei* at flowering is significantly shorter (5-15 m) than is the case for *C. utan* (20-30 m) but its inflorescence is larger and less compact than in *C utan*. There is very little overlap in the geographical distribution of the two, with *C. lecomtei* being distributed from eastern Thailand through Cambodia and Laos into Vietnam while *C. utan* has a more southerly coastal and riverine distribution.

DISTRIBUTION AND ECOLOGY

Fox (1977), like others before him (Banks 1771; Cook 1773), was deeply impressed with the lontar's adaptation and productivity in the harsh, rocky semi-arid environment of the island of Savu. Ormeling (1956) writing about the alluvial coastal plains of west Timor observed that lontar and gewang are pioneer species on seasonally burned lands, forming palm savannahs often in the wake of swidden cultivation.

Throughout the tropics of South and Southeast Asia, *B. flabellifer* L. and species of the genus *Corypha* L. occupy niches on semi-arid riverine plains and nearby foothills that most other Arecaceae with their wet-tropical origins eschew. Nevertheless, neither *Corypha* nor *Borassus* quite escape their humid tropical evolutionary past for they rarely thrive far from riverine plains or underground water sources. In the particular case of *B. heineanus* Becc., signs of its tropical forest adaptation are apparent in such a characteristic as the dorsi-ventral differentiation of its leaf lamina anatomy that contrasts with the isolateral leaf anatomy of other *Borassus* species adapted to the higher light intensity of their usual savannah habitats.

Borassus L.

It is an intriguing fact that the genus *Borassus* appears to be almost entirely absent from the Philippine archipelago. From past literature and feedback from researchers around the world, Kovoor (1983) assembled an approximate distribution for the genus which correlates quite closely with the map produced by Bayton (2007) based on herbarium specimens. Table 1 summarizes this distribution; apart from a few outliers, *Borassus* has a tropical distribution extending from West Africa through South Asia to Mainland Southeast Asia and eastern Indonesia but not to the Philippines.

As was noted above, Fox (1977) followed Beccari in maintaining separate species status, *B. sundaicus* Becc., for the lontar palm of Indonesia, a viewpoint that was later overturned by the taxonomic studies of Tjitrosoepomo and Pudjoarinto (1983). However, Fox was not inclined to attribute independent cultural origins for many of the practices he observed in the utilization of the *Borassus* palm in south-eastern Indonesia. While recording certain unique features in the technology employed in exploiting the palms on the islands of Roti and Savu, he nevertheless observed the overall resemblance of this technology to that in other significant centres of *Borassus*-use such as on the island of Madura off Java and in Tamil Nadu, India. According to Fox, Rotinese oral traditions maintained that the technique of tapping the lontar palm for its sugar had not originally been part of their own practices but had been brought to them via the islands of Ndao or Savu islands by legendary figures from western regions of Indonesia. Fox reckoned that "on balance, there is no conclusive evidence of origin but present appearances point clearly to India and Ceylon."

To the north of Indonesia, in Cambodia, the Indian elements in the *Borassus*-tapping traditions of the Khmer kingdoms are unmistakable. Likewise, *Borassus* planting and tapping remains today a significant part of the rural economy of Buddhist Pagan in Myanmar (Figures 3 and 6). On the other hand, the practice of tapping *Borassus* palms for sugar has never been a significant part of Philippine traditions. It is surely no coincidence that the Philippines for most of their history remained largely outside the sphere of influence of the Indianized kingdoms.

Kovoor (1983) had few reservations in asserting that the distribution of *Borassus* in Southeast Asia is a reflection of the dispersion of Indian cultural influence in the region. Based on biochemical studies (Kovoor and Hussein, 1983), he acknowledged a distinct biological difference between Asian *B. flabellifer* and *B. aethiopum*, but nevertheless appeared to imply that the designation of the two branches of *Borassus* as separate species was more for pragmatic reasons than reflecting a discontinuity with deep prehistorical roots.

On the Ivory Coast of West Africa, a long term study of an area of *Borassus aethiopum* savanna in a protected forest reserve has revealed much of the dynamics of the *B. aethiopum* life cycle in the absence of normal pressure from human exploitation (Gignoux et al. 2007). In common with other *Borassus*, but in stark contrast to species of *Corypha*, the fruits of the palm are large and heavy (0.5-1.5 kg), falling to the ground in relatively small numbers of 50-100 fruit per tree in any single year (Barot et al. 1999). In the protected forest, free from large animals (baboons and elephants for example), the majority of *B. aethiopum* fruits (normally carrying 3 seed each) are dispersed no more than 10 metres away from the mother tree. There is negligible seed dormancy and seed germination is remote-tubular. The hyperphyll (i.e. cotyledonary petiole) grows quickly to a length of up to 30-50 cm, burying the sprouting embryo well underground where it largely escapes the effects of normal seasonal grass fires (Uhl and Dransfield 1987; Tomlinson and Jeffrey 1990). The same is almost certainly the case for *B. flabellifer* in natural savannas such as those arising in fired lands in West Timor, Indonesia (Figure 3).

Fire plays a major part in contributing to the dominance of *Borassus* in such savanna lands (Ormeling 1956; Gignoux et al. 2007). In each of the life stages of the developing palm, there are features which confer a competitive advantage in the presence of fire. When the first entire leaves of *B. aethiopum* seedlings emerge from the ground, no part of the stem is visible. During the subsequent succession of one or two split leaves that

slowly develop for as long as ten years, the stem widens to attain its full juvenile girth but with its terminal bud still remaining below ground level, safe from the effects of fire. At the time when the first fully expanded costapalmate leaves appear, the apical bud remains relatively well protected from fire by a widening crown of green leaves (Tomlinson and Jeffrey 1990; Barot and Gignoux 1999). However, it is at this stage, before its stem elongates to lift the crown above the height of the predominant grass species that the palm is at its most vulnerable. As the trunks of juveniles develop and the initial leaf laminas begin to age and drop off, their petioles remain attached to the stem conferring another mechanism of protection from fire; it is the old dead leaf bases that draw the flame rather than the green crown with its protected apical bud. These petioles remain until the stem is about ten metres high. As the palms reaches sexual maturity, the dead leaves fall off as entire units, leaving the trunks bare (Tomlinson and Jeffrey 1990).

Palms at the onset of maturity are about 10 metres high and initially bear 10 to 25 living leaves, but by the final stages of life can attain 25-30 metres in height. In the case of *B. aethiopum* and the other two African species, *B. madagascariensis* and *B. akeassii*, the onset of sexual maturity is almost always heralded by a characteristic swelling of the trunk both in male and female palms (Dransfield and Beentje 1995; Bayton, 2007). In *B. flabellifer*, on the other hand, such swelling of the trunk is not observed either in the Indian subcontinent or in Southeast Asia.

Adult palms of *B. aethiopum* have a high root density within 3 metres of the main trunk (in which zone 75% of the mature fruit fall) and appear to be very effective scavengers of scarce soil nutrients. This presents considerable competitive pressures for their seedlings. In the absence of large animal dispersal of fruits, seedlings emerge within ten metres of the mother palm. However, Barot et al. (1999) suggest that *B. aethiopum* has evolved its big fleshy fruits to attract dispersion by large herbivores. This raises questions about the evolutionary connections between the African and Asian branches of *Borassus* and indeed about the differences in evolutionary pressures that produced the markedly different reproductive behaviors of *Borassus* and *Corypha*.

Corypha L.

Tracing the natural distributions of the two genera is difficult because both have wide human usage and many of their habitats have been transformed by the agricultural revolution (Table 1). Thus the species *C. taliera* last observed growing in "natural" circumstances in 1979 (in Birbhum, West Bengal) is now declared to be extinct in the wild (IUCN 2016). Moreover, even for the closely related species *C. umbraculifera*, its apparent natural distribution in Kerala and places like Kumta and the Yellapur Ghats in Karnataka of South West India, as well as in northern Sri Lanka, are greatly influenced by human usage. The occasional plants observed in Myanmar and Thailand are most commonly associated with Buddhist temple compounds. Already by the late 19th Century, Joseph

Hooker was writing of *C. umbraculifera*: "*This must be a native palm* [of Ceylon] *but I have never seen it in original jungle. Of the vast number of seedlings which come up near the parent tree, very few arrive at maturity, the young leaves being continually cut. Beddome* [of the Madras Forest Department] *remarks that he has never seen it wild in S. India.*" (Hooker, cited in Blatter 1926).

In contrast to *C. taliera* and *C. umbraculifera*, the gewang palm, *C. utan,* was almost certainly part of the indigenous flora of Eastern India and Southeast Asia (Table 1). In Northern Australia, there are significant pockets of *C. utan* in east Arnhem Land (Liddle et al. 1994) and *Corypha*-dominated riverine forest strips occupying hundreds of hectares in Cape York Peninsula (Frith and Frith 1995). Dowe (2010) records: "*in the Northern Territory it occurs on the floodplains of the Tomkinson and Liverpool Rivers and the Arafura Swamp, and in Queensland in Cape York Peninsula from the lower reaches of Mitchell River in the west, throughout the peninsula (except the far north) to Normanby River in the east. It occurs in groves, small groups or scattered individuals associated with floodplain channels, anabranches, billabongs and seasonally wet depressions, and as a riparian element on the banks of seasonally flooded streams and rivers, as the dominant tree or as a canopy element where large trees are present*" (see Figure 6).

In the small, conserved riverine forest of Bipolo, West Timor, Indonesia, giant gewang trees in the final stage of life are found in flower in all months of the year (Figures 2 and 6). They are prolific seeders and beneath open gaps in the forest canopy, vast numbers of seedlings emerge. It is likely that germination of seeds is inhibited by modified light conditions beneath the canopy proper, as is found in several other palm species of tropical forests (Latifah et al. 2014). Under natural conditions very few of the seedlings survive to form mature palms within the vicinity of the mother palm, but near human habitations large uniform groves of the single species are observed, which are almost certainly artifacts of human exploitation (Figure 2). The fruit walls are food for birds, bats, and small animals which can disperse the small but very hard seeds far and wide (Dowe 2010).

Brown and Merrill (1919) noted that *C. utan* also occurs very widely dispersed in the Philippines extending from northern Luzon, southern Mindanao, Palawan, to the Sulu Archipelago as scattered palms and occasionally planted groves. In some places it is "exceedingly abundant, gregarious, and locally the dominant species" amounting to thousands of hectares: "*in the Rio Chico region, Pampanga Province, Luzon ... there is ... a buri forest covering approximately 5,000 hectares .... with 9,205,710 buri palms mostly over 2 meters in height but without clear trunks. Of such sizes, there were 6,368,432 palms on the area. Buri is especially abundant in the provinces of Pangasinan, Pampanga, Tayabas, Camarines, and Sorsogon in Luzon, and in parts of the islands of Palawan, Mindoro, Panay, Neeros, Masbate, Cebu, Bohol, and Mindanao*".

UTILIZATION

Borassus L.

As is the case in Africa, the most significant use of the *Borassus* palm in Asia is for its sugary sap that can be tapped and processed into a range of end-products: a sugary drink, ('sweet toddy' known as 'nira' in some parts of Indonesia); palm wine ('tuak'); vinegar ('cuka'); distilled spirits ('arak'); and a variety of evaporated products ranging from raw brown sugar, through treacle, to crystallized and candied sugar (Batter 1926; Davis 1988). In eastern Indonesia, Fox (1977) estimated that at the height of the tapping season, a mature lontar palm could yields up to 6.7 litres of juice (or 1 kg of evaporated sugar

Table 1. The core distributions for the genera *Corypha* L. and *Borassu*s L. according to a selection of published records.

Species	Country	Sources of information [1]
Corypha		
utan	**Australia** (North Queensland,Northern Territory); **Papua New Guinea** (Western Province); **Indonesia** (Maluku, Sulawesi, Lesser Sunda Islands, Kalimantan, Java; Sumatra); **Philippines** (Luzon, Mindoro, Palawan, Cebu, Mindanao, Sulu Archipelago); **Cambodia**; **Vietnam**; **Laos**; **Thailand** (Peninsula); **Malaysia** (Sabah, Kedah); **Myanmar** (Tanintharyi); **Bangladesh**; **India** (Andaman Is; West Bengal, Assam).	Van Rheede Drakenstein (1678): *Cum* Rumphius (1741): *Cut* Lamarck (1786): *Cut* Roxburgh (1820): *Ct; Cum* Roxburgh (1832): *Cut; Cum* Griffith (1850): *Cut;Cum*
microclada	**Philippines** (Biliran Island only).	Lecomte (1917): *Cl*
lecomtei	**Vietnam** (Cochinchina); **Cambodia**; **Laos**; **Thailand** (Prachinburi Province).	Brown & Merrill (1919): *Cut* Blatter (1926): *Cut*; Ct; *Cum*
taliera	**Extinct in the wild**: **Bangladesh** (Dhaka, only in cultivation); **India** (West Bengal, only in cultivation).	Heyne (1927): *Cut* Beccari (1933): Cut; Cm; Cl; Ct; Cum Burkill (1966): *Cut*
umbraculifera	**Sri Lanka**; **India** (Tamil Nadu, Kerala, Karnataka, Maharashtra); **Cambodia**, **Thailand**, and **Myanmar** (only in cultivation).	Johnson IUCN (1998): *Ct* Basu et al. (1987) Cut; *Ct*; Cum Barfod et al. (2001): *Cut* Henderson (2009): *Cut*; *Cl*; *Ct; Cum* Dowe (2010): *Cut* Rukan et al. (2010): *Cut*; *Cl*
***Borassu*s**		
heineanus	**Papua New Guinea** (East Sepik and West Sepik provinces); **Indonesia** (Papua Province: Jayapura and Sarmi regencies).	Rheede tot Drakenstein (1678): *Bf* Rumphius (1741): *Bf*
flabellifer	**Indonesia** (Papua, Maluku, Sulawesi, Lesser Sunda Islands, Madura, Java, Sumatra); **Vietnam**; **Cambodia** (Kandal, Takeo, Kompong Chhnang, Kompong Speu); **Laos**; **China** (South Central); **Thailand** (Bangkok, Nonthaburi, Phichit, Rayong and Songkhla); **Malaysia** (Kelantan state); **Myanmar** (Mandalay, Magwe); **Bangladesh** (Chittagong, Chittagong Hill Tracts and Dhaka); **Sri Lanka** (Eastern, North Western, Northern); **India** (West Bengal, Odisha, Tamil Nadu, Uttar Pradesh, Karnataka; Maharashtra); **Yemen** (Socotra Island).	Martius (1838): *Bf*; *Bae* Ferguson (1850): *Bf* Jumelle & Perrier (1913): *Bm* Beccari (1914): *Bh*; *Bf*; *Bm*; *Bae* Beccari (1924): *Bh; Bf; Bm; Bae* Heyne (1927): *Bf* Chevalier (1949): *Bae* Portères (1964): *Bae*
madagascariensis	**Madagascar** (Mahajanga and Toliara).	Burkill (1966): *Bf*
aethiopum	**Madagascar** (Antsiranana, Nosy Be); **Comoros**: **Mozambique**; **South Africa** (Limpopo); **Zimbabwe** (Masvingo); **Zambia** (Southern province); **Malawi**; **Tanzania** (Mara, Pemba South, Pemba Island, Tanga); **Kenya** (Coast province); **Ethiopia** (Benishangul-Gumaz, Gambela); **South Sudan** (Junqali, Upper Nile); **Uganda**; **Democratic Republic of the Congo** (Kassai-Occidental and Sud-Kivu);**Central African Republic**; **Chad**; **Cameroon**; **Gabon**;**Nigeria** (Delta and Niger states); **Niger** (Dosso department); **Benin**; **Togo**; **Ghana** (Ashanti, Greater Accra regions); **Burkina-Faso** (Ganzourgou, Kompienga and Tapoa provinces); **Ivory Coast** (Bas-Sassandra, Lagunes and Sud-Comoe regions); **Mali** (Kayes, Djenné); **Guinea**; Guinea-Bissau; **Senegal** (Matam, Tambacounda, Thiès, Cap-Vert); **The Gambia; Mauritania** (Trarza).	Fox (1977): *Bf* Lubeigt (1982): *Bf* Kovoor (1983): *Bf*; *Bae* Kovoor & Hussein (1983): *Bae* Paulas & Muthukrishnan (1983): *Bf* Tjitrosoepomo & Pudjoarinto (1983): *Bf* Uhl & Dransfield (1987): *Bf*; *Bae* Davis and Johnson (1987): *Bf* Dransfield & Beentje (1995): *Bm; Bae* Aké Assi & Guinko (1996): *Bak* Barfod et al. (2001): *Bh* Sambou et al. (2002): *Bae* Bayton et al. (2006): *Bm*
akeassii	**Democratic Republic of the Congo** (Kassai-Occidental province); **Central African Republic**; **Nigeria**; **Niger**; **Benin**;**Burkina Faso** (Comoé, Houet, Kadiogo); **Ivory Coast**; **Mali**; **Senegal** (Kaolack, Louga, Thiès)	Bayton (2007): *Bh*; *Bf*; *Bm*; *Bae; Bak*

[1]Note: Meanings for the codes following the author citations are: *Cl – C. lecomtei*; *Cm – C. microclada*; *Ct – C. taliera*; *Cum– C. umbraculifera*; *Cut – C. utan*; *Bae – B. aethiopum*; *Bak – B. akeassii*; *Bf – B. flabellifer*; *Bm – B. madagascariensis; Bh– B. heineanus.*
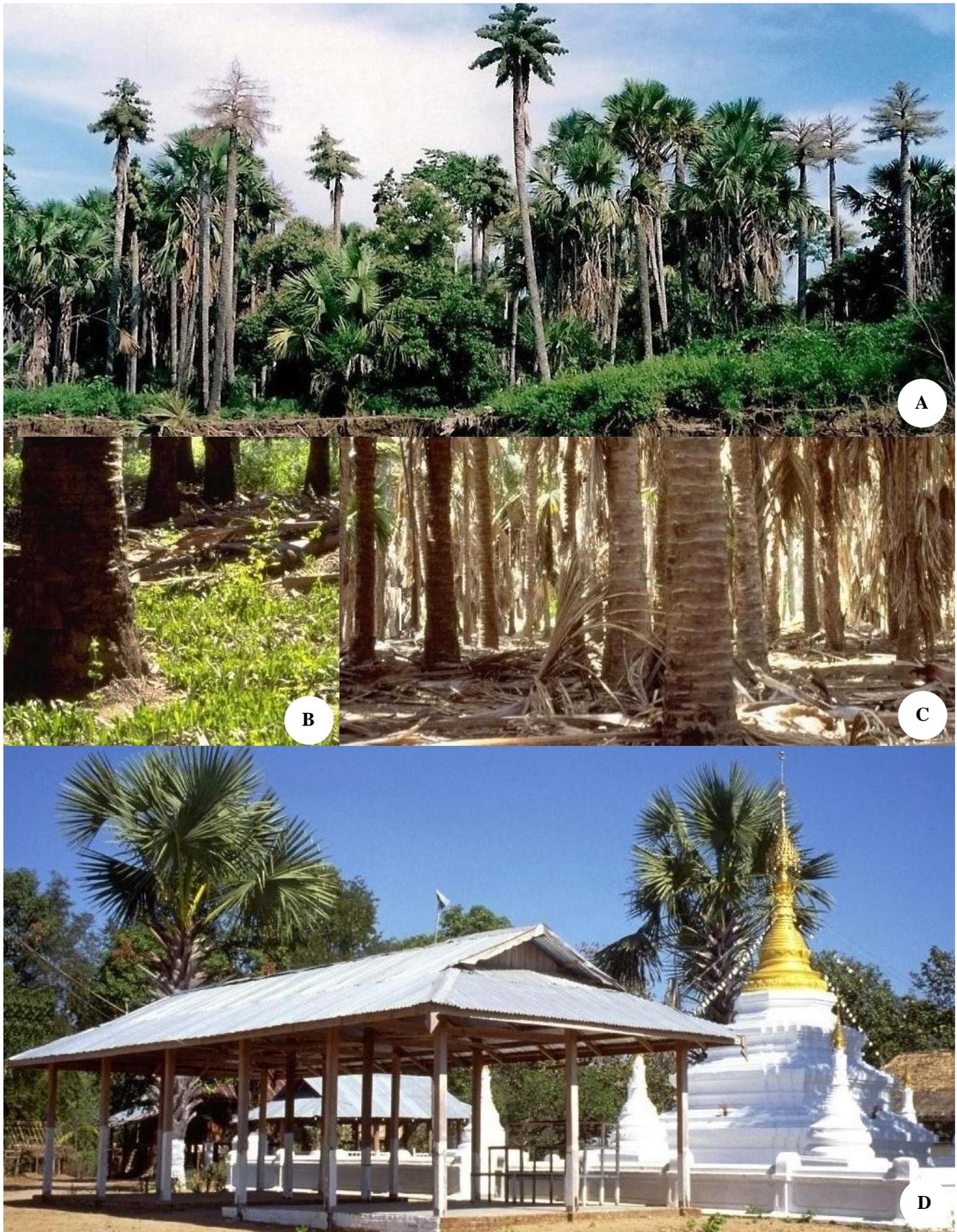
Figure 2. *Corypha* spp. and their habitats. A. Mature riparian forest dominated by *Corypha utan* Lam; B. Abundant *C. utan* seedling germination, at forest edge; C. Exclusion of competing vegetation in a 'managed' self-seeded *C. utan* 'mono-crop' nearby (A-C: Bipolo, West Timor, East Nusa Tenggara, Indonesia; 1995); D. *Corypha* sp. planted and maintained in a temple complex (Kyaukme, Shan State, Myanmar, 1998)
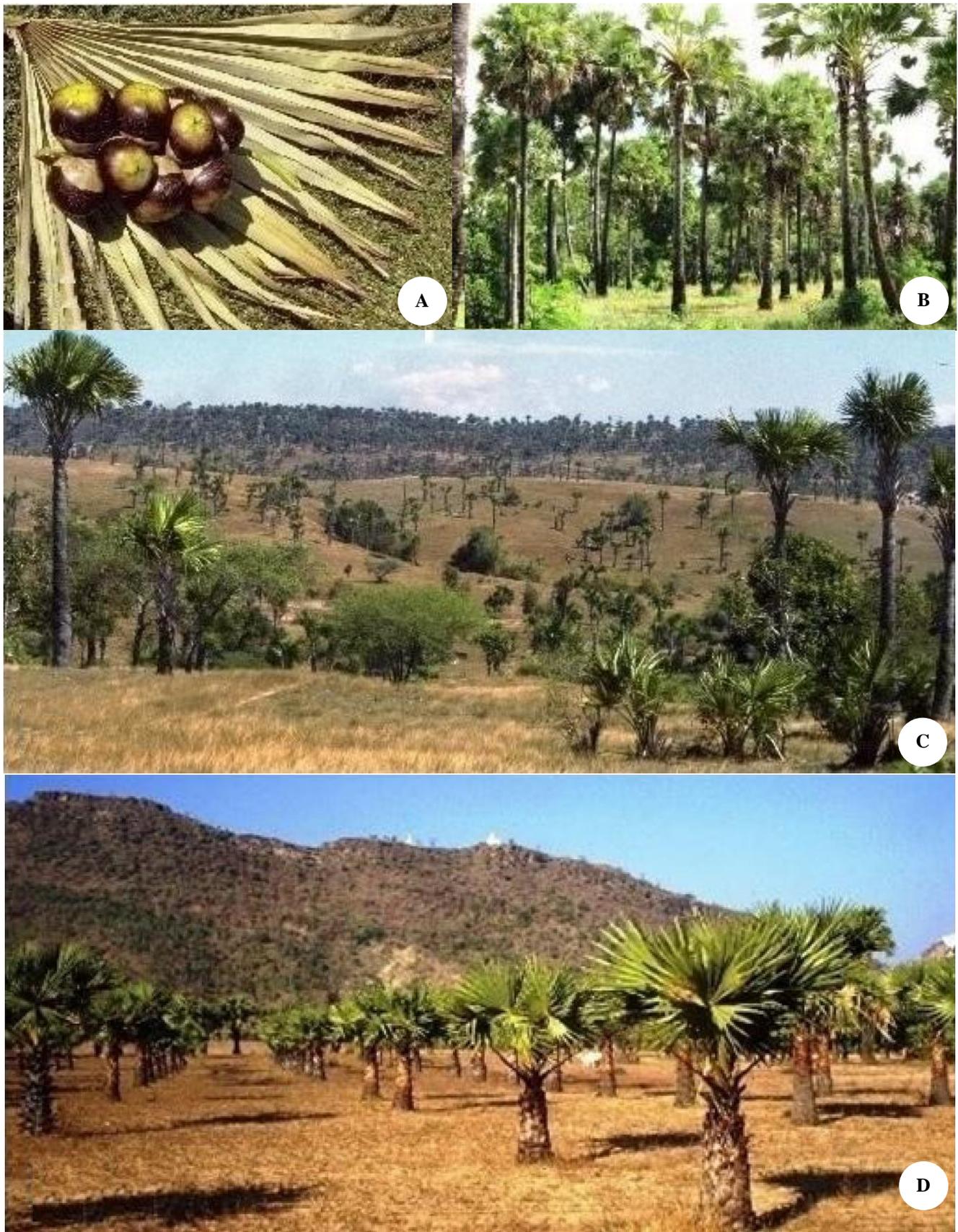
Figure 3. *Borassus flabellifer* L. and its diverse habitats. A. Typical leaf and fruit of a pistillate lontar palm; B. Mature palm grove (Sumenep, Madura Island, East Java, Indonesia, 2016); C. Minimum care lontar grove in savannah foothills (Kupang, West Timor, East Nusa Tenggara, Indonesia, 1995); D. Palm monocrop (Nyaung-U District, Mandalay Division, Myanmar, 1998).

syrup) per day. Khieu Borin (1996) has reported similar yields in Cambodia. Fox described in detail the technology employed in Roti and Savu to extract and utilize the sugary sap, and then compared these techniques with published accounts of those in Madura and Southern India. Kovoor (1983) summarized the variation in practices found in India, Sri Lanka and Southeast Asia. He noted that the Asian method for extracting the sap from the rachillae of inflorescences (of either male or female palms) has distinct advantages over the technique employed in much of Africa where the sap is usually extracted from the terminal growing point leading to a quick end to the productive life of the palm (Sambou et al. 2002). Dalibard (1999) has compared the sugar producing capacity of *Borassus flabellifer* with that of a number of other palm genera including the other important Indonesian sugar palm *Arenga pinnata* (Wurmb) Merr. that is better adapted to higher rainfall ecosystems than is the lontar (Mogea et al. 1991).

The scientific literature of the colonial era recognized that tapping the palm for its sugary sap was just one of the wide range of technologies traditional societies had developed to exploit the versatility of the hardy *Borassus* palm. Ferguson's (1850) classic account suggested that

exploitation of the palm in India could be traced back thousands of years and referred to the 801 uses for the palm catalogued for example in the "Tala Vilasam", a famous Tamil poem extolling its virtues. Among the products the 'Tree of Life' was listed as providing were: the edible, jelly-like, immature endosperm of the seed (which in modern times in some countries is canned, preserved in syrup); the sweet, mesocarp pulp enveloping the pyrenes of the mature fruits that can be sun dried or roasted (Rumphius 1741); the tender apical bud known as the palm 'heart'; the underground seedling (Figure 4) with its starch-filled, geotropic, apocole (cotyledonary sheath) and upward growing hyperphyll (cotyledonary petiole of the first bladeless leaf) (Padmanabhan et al. 1978); mature palm trunks used as pillars and posts; and narrow planks split from tough outer layers of the mature trunk used as rafters for roofing supports (Blatter, 1926); strong fibres extracted from the leaf bases and used for a wide variety of purposes including cordage and as bristles in scrubbing brushes (Davis and Johnson 1987); whole leaf laminas or their leaflets that can be used for thatch, and to make fans, hats, mats, sails, as well as a diversity of plaited containers (Figure 4); and individual leaflet portions of the laminas that were used in the past in great numbers as writing media to communicate Hindu and/or Buddhist sacred teachings (Bhoi 2010).

One example only of the complexity of this technology and the depth of the literature describing it is quoted here from the venerable account of the lontar written by Rumphius (1741). Here, he is describing the utilisation of the pulpy endocarp of the mature fruit to produce a foodstuff known in Sri Lanka as 'punatoo': "*after the ripe fruits … have been collected, the stalk and the cups* [presumably, the persistent tepals] *are twisted off with the hands, the outer rind is stripped off, and the peeled fruit are washed … then pressed out … until all the yellow juice*

has been drawn out; this is … repeated twice, thrice … and it assumes a thick consistency; … they spread large mats … on which they then pour out the liquor … then leave it to dry for one day and on the next day they pour fresh juice, which is again left to dry, repeating the same labour until this cake has acquired the thickness of three fingers … When this becomes a hard as cheese, it is cut into square pieces … placed in baskets, and sprinkled … with water in which salt has been dissolved. … And these baskets … are … smoked for several days; but not too much lest the Punata become bitter. … The people of Makassar prepare the fruits in a much more convenient manner, nor do they spend so much labor. They merely press out the juice, and then pour it into large platters and mix it with the rice-meal, and prepare many kinds of foods with it." (Rumphius 1741).

Fox (1977) noted that many of the uses listed by Ferguson and others in India (including the making of punatoo) were not practiced in the palm cultures of eastern Indonesia. On the other hand, there were a number of uses of *Borassus* unique to these islands not only for making the iconic headwear of the Rotinese and their unique musical instrument the 'sesandu', but also innovations in the tapping and processing of sugar. The sap with a soluble sugar content exceeding 10% provides not only a direct energy input in the diet of palm-tapping communities, but also sustains the important small livestock component of the economy (Khieu Borin 1996; Dalibard 1999). Fox observed that on Roti the lontar is so plentiful that rarely is there a need to plant it out. However, in Savu where there is greater dependence on the palm, it is often carefully planted, sometimes spaced out in walled off groves, sometimes in rows on rice bunds, at other times as wind breaks and boundary markers around plots of sorghum, annual crops and fruit trees (Figure 6).

In Tamil Nadu, the number of palmyra palms has been estimated to be as many as 40 million (Kovoor 1983), which traditionally has sustained the livelihoods of thousands of poor village communities. In modern times there has been great social change in the region and the palm economy is often viewed as a legacy of the past (Hardgrave 1969; Depommier 2003).

Perhaps nowhere is the present-day utilization of *Borassus* more sophisticated than in the thousands of hectares of neatly planted rows distributed along the eastern bank of the Ayeyarwady River, south of Pagan in Myanmar (Figures 4 and 6). Lubeigt (1982) has used the term "Palm Civilizations" to describe the kind of economy that evolved in the Indianized centres of Southeast Asia, for example in the Buddhist principalities of Thailand and the Khmer kingdom of Cambodia.

South of Pagan, the *Borassus* palms are planted out in a checkerboard fashion as wind breaks around annual crops like maize, sorghum, pigeon pea, sesame and chilli (Figure 4). Occasionally, there are orchard-like blocks of *Borassus* palms (Figure 3). Generally, it is the land-owning farmer who possesses the palms. These are contracted out to palm-climbing specialists who live a hard and sometimes dangerous life tapping the sugary sap of about 30 palms a day; this is boiled, evaporated and processed by the

climber's family into a range of marketable sugar end-products. The important study of Khieu Borin (1996) in Cambodia suggests that producing crystallized sugar from the sap is becoming increasingly unsustainable because of the quantities of scarce woody fuel required in boiling down the syrup. However, the study also showed that using the sugary sap directly as the principle energy in livestock rations results in a much higher economic return with fewer negative consequences for the environment.

In the island of Madura, off the Northeast east of Java, another locality of intensive Borassus use, palms were traditionally planted close together in rows with their canopies touching so that bamboo scaffolding could enable tappers to pass from one palm to another without the need to ascend and descend individual trees in the process of collecting the sugary sap from the tapped inflorescence rachillae (Gebius and Abdul Kadir 1929). The legacy of this can be seen today (Figure 3) even though in modern times sugar tapping is a less mainstream activity than it was in the past. Harvesting the leaf blade for a wide range of uses continues today on Madura as in Tamil Nadu, India, but in the age of plastic is of less commercial importance than it assumed in the 1920s.

In most parts of this "Palm Civilization", the life of the climber and his family has often been a hand-to-mouth existence. In Tamil Nadu, for example, the social complexity of the palm-tapping way of life is a hotly contested political arena (Vannan 2011). Nevertheless, the palm-based economy is often less precarious than the alternatives that might be available. Fox (1977) determined that the palm-tapping of the Savunese and Rotinese has provided a more secure subsistence platform from which to launch into other economic pursuit than is possible for shifting cultivator communities living on the proceeds of rain-fed annual crops and livestock grazing in much of semi-arid Nusa Tenggara Timur. On dry, rocky Savu it is lontar alone that has been pivotal to this stability, but in the better watered Roti gewang has been almost as important.

Figure 4. Economic use of *Borassus flabellifer* L. A. Inflorescence rachillae tapped for palm sugar. Pagan, Myanmar, 1998. B. Ingenious use of palm leaves as seen here in the vessel used to catch the sugary sap. Waingapu, East Sumba, 2013. C. Harvested leaf parts are sold for a wide range of uses. Sumenep, Madura, 2016. D. The palm fruit can be eaten fresh and or even canned, but the seeds from the fruit can be sprouted by burying them in pits. The large sprouted seeds are sold as seen here in Thiri Mingalar Market in Yangon, 1998.

Corypha L.

It is easy to underestimate the contribution that *C. utan* has made to the way of life of the eastern end of the Malesian archipelago. Even in modern times the leaf petioles of the gewang are still used as an excellent simple building material more than 50% of traditional housing in lowland Timor and surrounding islands (Figure 5). Unlike the timber of the main trunk and the leaf lamina which are of mediocre value as building materials compared to that of the lontar, the long, straight, tough leaf petioles of the gewang allow for the construction of cheap wall-panelling that compares favorably with other traditional panelling.

In the Philippines, a substantial export industry has long existed in products crafted from the leaves of the palm they call 'buri' (Brown and Merrill 1919). Calapis et al. (2011) record that in the year 2000 the size of this export amounted to $53 million. Of greatest value is the fine fibre bundles called 'buntal' extracted from *C. utan* leaf petioles and converted into such things as the fashionable "Lucban" hats and hand bags (The Buri Bag Project 2016). But there are several other leaf materials with different properties ('buri' from the mature leaves and 'raffia' from the unfolded immature leaves) that have niche uses for cordage, basketry, matting, brushes and wrapping materials of export quality, but also for humbler local purposes (fencing, fuel, carrying bags and the like).

There is a complementarity in the use of *Borassus* and *Corypha* in locations such as the island of Roti, Indonesia. In the Indian subcontinent, the superiority of *Corypha* leaves over *Borassus* was recognized from ancient times for some purposes (e.g. as a preferred writing material on which to record their sacred texts), but the sheer versatility of the *Borassus* trees appears to have led to the demise of *Corypha* in places where perhaps it was once more abundant. Nevertheless, this has come at a cost; for in Tamil Nadu where heavy use of *Borassus flabellifer* is made for its leaves, cannibalism of the leaf crown is believed to reduce sugar yields, weaken the trees and even lead to their demise (Davis and Johnson, 1987).

Similarly, in the case of Madura, the exploitation of Borassus for its leaves in the 1920s was believed to be having deleterious effects on the commercial production of palm sugar from the island (Gebuis and Abdul Kadir, 1929). This situation might have been worse if there hadn't been a relative abundance of gewang palms ('pocok') on the island. At that time, the leaves of the *Corypha* palms on Madura were woven into a high quality matting ('agel') which was widely used as packaging for the export of agricultural produce including coffee from Java and Sumatra to overseas markets (Heyne 1927).

Pith from the mature gewang's trunk, known in North Sulawesi as 'gumbar' and in West Timor as 'putak' (Heyne 1927; Bamualin et al. 1990; Umar et al. 1991), is processed into sago. Even today, use is made of the gewang's 'putak' as animal food (Ginting-Moenthe et al. 2002) and of its sago for occasional human food (Figure 5). The gewang can also be tapped to produce palm sugar (Figure 5), although this is rarely done in locations where lontar is plentiful (Rumphius 1741; Heyne 1927, Dalibard 1999).

ORIGINS

Borassus L.

The Coryphoid tribe Borasseae is classified into two subtribes each with four genera; namely subtribe Lataniinae (consisting of genera *Borassus* L., *Borassodendron* Becc., *Lodoicea* Comm. ex DC, and *Latania* Comm. ex Juss.); and subtribe Hyphaeninae (consisting of *Bismarckia* Hildebr. & H. Wendl., *Satranala* J. Dransf. & Beentje, *Medemia* Wurttenbe ex H. Wendle., and *Hyphaene* Gaertn.). The tribe is centered on the Indian Ocean, with its westernmost margin in West Africa and easternmost in Papua New Guinea.

Bayton (2005) carried out a phylogenetic analysis of the Borasseae and its outgroups, based on the nucleotide sequencing of five well characterized chloroplast regions and two low copy nuclear genes. The analysis provided broad support for the taxonomic consensus summarized by Dransfield et al. (2008); the Borasseae, its subtribes Hyphaeninae and Lataniinae, as well as the genus *Borassus* L. were each confirmed to be monophylous.

Bayton (2005) went on to examine the issue of whether the nucleotide sequencing data could provide an estimate of just when it was that the constituent genera of the Borasseae began to diverge from one another. Initial attempts to calibrate the dating for the evolution of the tribe based on the estimate of 7.8 Mya for the volcanic uplifting and formation of the Mascarene island chain where the endemic genus *Latania* currently grows, produced unrealistically late estimates for the timing of key evolutionary events. A more plausible scenario was obtained by calibrating the evolutionary tree obtained from the sequencing data with well characterized events in the fossil record, such as the occurrence of the Coryphoid fossil, *Sabalites magothiensis* (Berry) Berry, estimated by independent methods (Berry 1914) to be from the Upper Cretaceous, around 80 Mya.

Based on this admittedly preliminary analysis, Bayton (2005) estimated that the two subtribes comprising the Borasseae diverged from one another about 47 Mya in the Eocene, that *Borassus* diverged from its sister genus *Borassodendron* about 35 Mya at the end of the Eocene, and that the widely dispersed semi-arid adapted species of *Borassus* (*B. flabellifer* and *B. aethiopum* for example) diverged about 26 Mya from their sister *Borassus heineanus*, confined in modern times to the humid fringes of tropical northern New Guinea.

The recent phylogenetic analyses have also produced two surprises: (i) The taxon that appears to be phylogenetically closest to the Borasseae-*Corypha* clade is the Caryoteae (Uhl et al. 1995; Hahn 2002; Dransfield et al. 2005; Asmussen et al. 2006) a monophyletic tribe so distinct in its morphology from the rest of the Coryphoid subfamily that in previous taxonomic treatments of the Arecaceae it had been placed in the subfamily Arecoideae (Uhl and Dransfield 1987). (ii) On the basis of Bayton's (2005) analysis, the Borasseae diverged from their apparent sister clade, the genus *Corypha*, only 57 Mya; long after the initial break up of Gondwanaland, an event which some

authors had previously speculated to be the triggering mechanism for the dispersal and evolution of the Borasseae.

Corypha L.

In not all published phylogenies does *Corypha* emerge unequivocally as sister to the Borasseae (e.g. only 66% bootstrap support in the study of Asmussen et al. 2006). However, the monophyly of a clade incorporating the Caryoteae along with *Corypha* and Borasseae receives high bootstrap support (e.g. 91%, in Asmussen et al. 2006). Like *Corypha*, the tribe Caryoteae is distributed from south eastern Asia, through Melanesia (including Vanuatu in the case of the genus *Caryota*) to north eastern Australia.

According to Bayton's (2005) analysis, the clade 'Borasseae + *Corypha*' separated from the Caryoteae about 67 Mya at the end of the Cretaceous. This raises the counter-intuitive possibility that in the breakup of Gondwana, the ancestral line for this clade may have rafted on the Australian/New Guinea shard of the ancient southern continent rather than having arisen on the north-western fringes of the Indian Ocean.

On balance, this seems unlikely. The genus *Caryota* L. straddles the Wallace Line, with more species West of Sulawesi than East (Dransfield 1981). The same is true for the other Caryoteae genera, *Arenga* Labill. ex DC (Dransfield 1981; Mogea 2004) and *Wallichia* Roxb. (Henderson 2009) and for the next most closely related Coryphoid genera, *Kerriodoxa* J. Dransf., *Chuniophoenix* Burret and *Nannorrhops* H. Wendl. (Bayton 2005; Henderson 2009). Moreover, as we have seen, the genus *Corypha* has a distribution that spans the whole of south eastern Asia from Sri Lanka and the Andaman Islands through Indonesia to the Philippines. Is it remotely plausible that *Corypha* or its immediate evolutionary precursors could have evolved on the Australasian/New Guinea Plate?

There is evidence that the core monocot families may have had their beginnings in Gondwana in a nexus between what is now South America, Antarctica and Australasia during the favorable climatic period of the mid Cretaceous around 100 Mya (Janssen and Bremer 2004; Bremer and Janssen 2006). The earliest undisputed palm fossils are north American; *Sabalites* spp.- costapalmate leaves with apparent Coryphoid attributes-from the late mid Cretaceous to early Upper Cretaceous (Berry 1914). During the later favorable climates of the Palaeocene-Eocene (around 65-35 Mya), the palms underwent a significant radiation giving rise to most of the genera recognized today (Harley 2006; Dransfield et al. 2008).

The apparent triggering event in this process of evolution was the break-up of the super continent of Pangaea, beginning with the gradual separation of the land masses that would eventually become North America and Eurasia away from the Gondwana continent. A rift in Gondwana itself began opening up in the Lower Jurassic Epoch, 180-165 Mya, between the west coast of the African land mass and the east coast of the South American (McLoughlin 2001). The Madagascar/India shard broke away from Antarctica in the Lower Cretaceous (around 130 Mya), later coming into collision with the Eurasian plate during the Palaeocene (by 65-55 Mya) giving rise to the Himalayas in the Eocene about 45 Mya (Briggs 2003).

Meanwhile, South America and Australasia remained connected through Antarctica until well into the Paleogene Period and the breakup of this connection did not take place until as late as the Eocene around 50-35 Mya (Veevers et al. 1991; McLoughlin 2001). Once breaking its connection, New Guinea/Australasia /New Caledonia drifted north, until about 35 Mya, when New Guinea-the leading edge of the Australian Plate-began colliding with the south western part of the Pacific Plate in the Miocene (15 Mya) an event which pushed up the high mountains of the New Guinea range, and created the rain shadow that triggered increasing aridity in Australia from the late Miocene onwards (Metcalf 2002).

The extreme desiccation of the Australian continent has resulted in a comparatively impoverished modern day palm flora (54 species in 17 genera, compared with 280 species in 31 genera for the island of New Guinea; Dowe 2010), but fossil evidence suggests that palms were more widespread in Australasia in the past. The most diverse of the of Australia's modern day genera is *Livistona* R. Br., a genus in the Coryphoideae but one that is somewhat distantly related to *Corypha* and *Borassus* (Bayton 2005; Dransfield et al. 2005). There are currently 18 Australian species recognized in this genus and according to preliminary molecular investigations (Dowe 2001) these form a monophyletic clade that is sister to the other modern day *Livistona* species in Asia and further west. Some remote Australian outliers of the genus have been regarded as relics of a former more favorable climate left stranded by aridification; however recent research has suggested, at least in the case of *L. mariae* F. Muell., that isolation in Central Australia is more likely to have been the result of active dispersal, very possibly by Aboriginal people, in millennia past (Kondo et al. 2012).

Based on the molecular evidence, Dowe considers that, despite its diversity and well established presence, the Australian branch of *Livistona* is more likely to have evolved from a single ancient introduction from a Eurasian source rather than having arisen from an authotochonous element (Dowe 2001, 2010). The same, he believes, is likely to be the case for the gewang, *Corypha utan*. In the case of *C. utan*, he notes that there was a land bridge joining southern New Guinea to Cape York prior to 10,000 year ago and from south-western New Guinea to eastern Arnhem prior to 18,000 years ago (Chivas et al. 2001). Palms were present on the land-bridges as indicated by (unidentified) palm fossil pollen (Prebble et al. 2005). Today, *C. utan* populations of significant extent in Cape York and eastern Arnhem Land are cut off by the Torres Strait Sea from the populations in similar habitats on flood plains and riparian environments in southern New Guinea. The massive fruiting potential of the terminal hapaxanthic inflorescence producing seed small enough to be widely disseminated by southward migrating frugivorous birds (Dingle 2004) indicates that dispersal into tropical northern Australia is very likely an on-going phenomenon today despite the Torres Strait gap.

Figure 5. Economic uses of *Corypha utan* Lam. A. Wall paneling, roofing and fencing; B. Road-side sale of harvested leaf petioles (used in wall panels) and palm pith sections for animal feed; C. Platform high in a late stage palm from which inflorescence rachillae are tapped for palm sugar. D. Trunk of a felled palm being split for its sago; E. Palm pith ground, soaked and filtered to produce sago (Babau, West Timor, East Nusa Tenggara, Indonesia; 1995)

THREE HYPOTHESES

This review of recent advances in our taxonomic understanding of the pivotal role of *Borassus* and *Corypha* in the ecology and traditional economies of semi-humid parts of Malesia gives rise to three testable hypotheses. These are: (i) The gewang (*C. utan*) was a significant component of pre-agricultural economies of the Malesian archipelago in the periods prior to and during the peopling of continental Australia and well before the arrival of the definitively Indianising cultural influences of the last two millennia. (ii) The lontar (*B. flabellifer*) was present and utilized in the archipelago prior to its full flowering during the Indianized kingdoms of the Shailendras beginning around the 8th century CE. (iii) The palm family as a whole has been of greater importance in the sustenance of pre-agricultural peoples than has often been recognized, and that (in the words of Fox (1977): *"whole cultures can legitimately be described as adaptations to certain species of palms .... There is the doom palm (*Hyphaene thebaica*) of ancient Egypt and the date palm (*Phoenix dactylifera*) of the Middle East; the coconut palm (*Cocos nucifera*) and the oil palm (*Elaeis guineensis*)-commercially, the world's most exploited. Among sap-producing palms, there is the wild date palm (*Phoenix sylvestris*) of India, the sugar palm (*Arenga pinnata*) and the Nipa palm (*Nypa fruticans*) of Indonesia and the Philippines, and the African wine palm (*Raphia vinifera*). In a class by itself is the sago palm (*Metroxylon sagu*) and its related segregates. A single felled trunk of this species can actually yield up to 1,200 pounds of edible crude starch."*

Proto-agricultural origins

It is quite possible that *C. utan* pre-dated the arrival of man into the archipelago and was among the earliest of plant species to be used there. During the last ice age, which ended about 12,000 years ago, the climate of the region was more arid than it is now and large areas of the existing sea-bed between Southeast Asia and Australia was exposed (Chivas et al. 2001), providing a wider habitat for semi-arid species like the gewang. It is probable that the utilization of the gewang belonged originally to a foraging lifestyle and only later was it incorporated, virtually without domestication (in the genetic sense of the word) into the fringes of agricultural lifestyles. Sago processed
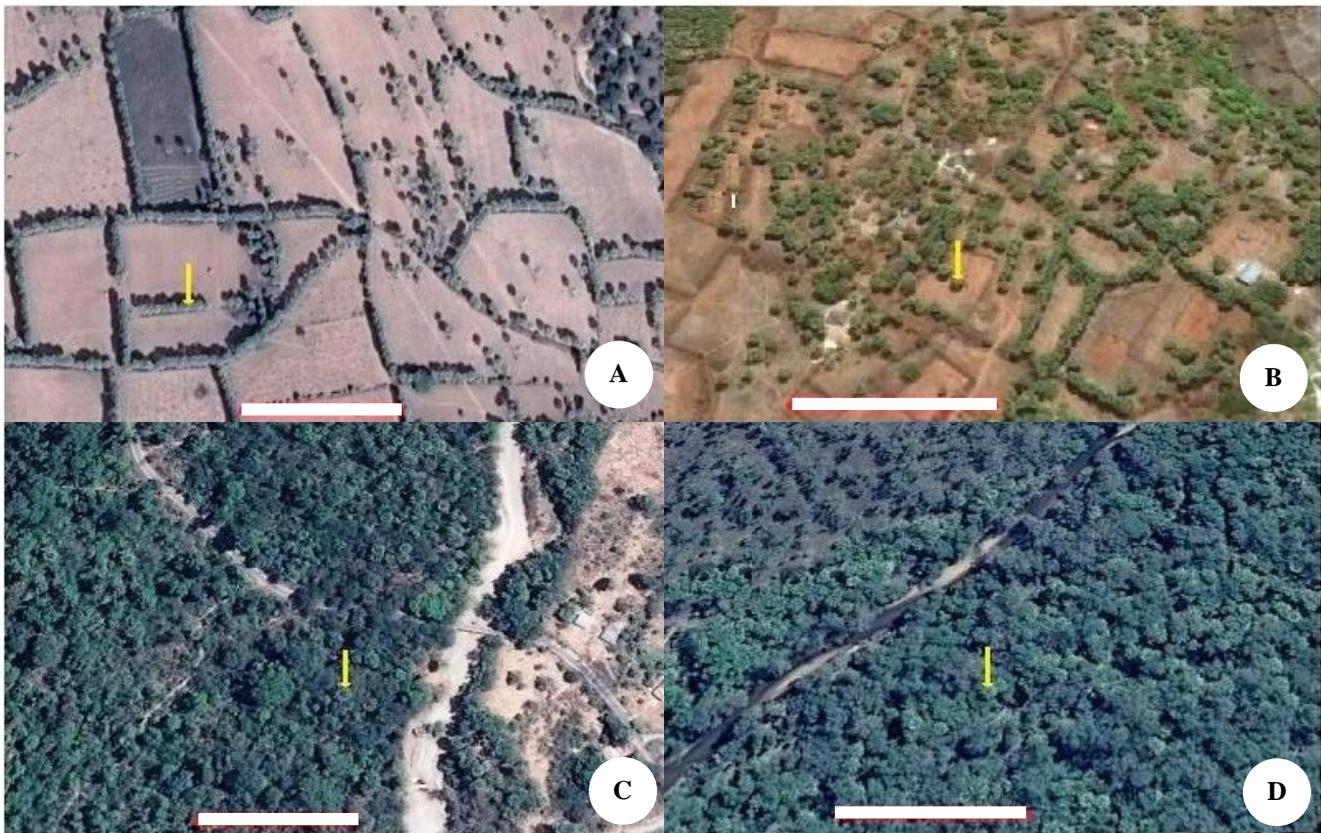
Figure 6. Aerial views of contrasting palm ecosystems (A-B *Borassus flabellifer* L.; C-D *Corypha utan* Lam) based on Google Earth© images [accessed late 2015]. A. Nyaung-U District, Mandalay Division, Myanmar (21^{0}04' N, 94^{0}57' E; 23/9/2015); B. Seba, Sabu Raijua Regency, NTT, Indonesia (10^{0}27' S, 121^0 53' E; 8/10/2012) C. Bipolo, Kupang Regency, NTT, Indonesia (10^{0}1' S, 123^{0}4' E; 23/9/2013); D. Normanby River, Lakefield National Park, Queensland, Australia (15^0 15' S, 144^{0}32' E; 8/8/2013). The length of the red line is equivalent to 100 m on the ground. Each yellow arrow points to a single mature palm. Bar = 1 km

from the mature gewang's trunk may have assumed greater significance in human nutrition in the past (Figure 5), before the arrival into the semi-arid parts of Southeast Asia of sorghum (from the west), domesticated rice (from the north) and maize, cassava and sweet potato (from the east); at a time when the principle carbohydrate sources would have been yams, cycads, water lilies, taro, water chestnut, wild millets, Job's Tears (*Coix* spp.) and wild rice species (Chang 1976; Fox 1977; Glover 1986; Jones and Meehan 1989).

In Sri Lanka, the sago of the talipot (*C. umbraculifera*) was prepared and used in a similar way to the gewang (*C. utan*) in Timor (Blatter, 1926). Interestingly, Jones and Meehan (1989) have recorded that the Gidjingali people in the Blyth River area of Arnhem Land, Australia, make use of the trunk pith of the gewang palm in a similar way to the sand palm, *Livistona humilis* R.Br., as an occasional food particularly in times of impending famine.

It is precisely in famine-avoidance that the great palms of the Arecaceae have provided such pivotal stability in the ecology and economy of Malesia. On the island of Roti, lontar trees are not planted; natural groves are manipulated (e.g. by thinning) and tapped to provide a year round supply of palm sugar, but as Fox (1977) determined, during the annual 'musim lapar' or 'paceklik' (literally, 'season of hunger'), the lontar provides for a substantial component of the total food energy requirements of the economy. In the islands of Roti and Savu, the traditional economies have supported human population densities in the order of 100 people/km (Figure 6) in contrast with densities of 50 people/km in the nearby non-lontar economies of Sumba and Timor.

Nevertheless, the local origins of lontar (*B. flabellifer*) are obscure. Kovoor (1983), following the taxonomic insights of Pudjoarinto (1982) and Tjitrosoepomo and Pudjoarinto (1983), proposed that lontar had its origins in India and perhaps even further west in Africa, and was carried to the east by human hands-paralleling the origins for crops like sorghum, sesame, cowpea, coffee and oil palm. There are undoubted Indian elements in the use of lontar, as is attested for example in the temple reliefs at Borobudur and the palm leaf writings of Bali (Hinzler 1993) mirroring those of India (Bhoi 2010) and the Southeast Asian kingdoms. However, it would be premature to assume that the existence of *B. flabellifer* in far eastern Indonesia is purely the result of its dispersal during the Indianising cultural waves of the archipelago's history.

though less so than in the past, on the many products of the palms.

Four particular lines of investigation would provide answers to some of the questions raised in this review: (i) a morphological and molecular-based taxonomic revision of the genus *Corypha,* (ii) a broad survey of the current ecological status of the two genera, of the kind that was carried out for *Borassus* by Kovoor (1983) thirty years ago. The IUCN assessment for *Corypha* in particular is in need of review, (iii) an economic and environmental evaluation of utilizing the sugary sap of the lontar palm in various livestock rations, (iv) an investigation into tissue-culture and cell-hybridization techniques in both genera. Large palm species have been difficult to handle using traditional taxonomic and genetic procedures; new lab-based technologies hold promise for intractable plant species like these.

However, the really important unanswered question is what the future holds for economies that have relied on these palms in the past. At the time when Davis and Johnson (1987) examined this issue for the State of Tamil Nadu, in India, there was at Srivilliputhur a well-established Palmyra Research Station with a germplasm collection representing a range of diversity for the species. However, since then the palmyra research program has slipped away, along with the search for quicker maturing palms with shorter more manageable plant height and for sap-harvesting technologies that could make the lot of the palm-tappers less hazardous and more profitable.

Wherever the exploitation of *Borassus* for its sugar and plentiful supply of useful leaf parts has existed it has been regarded as a subsistence industry. Palm-tappers have often belonged to a landless and poorly rewarded class of workers (Hardgrave 1969). Nevertheless, such persons do not go away. They persist, and the dependence on their precious palms continues (Vannan 2011; Walter Scott 2014).

ACKNOWLEDGEMENTS

CONCLUDING REMARKS

Species of *Borassus* L. and *Corypha* L. have long been part of the biological landscape of the semi-arid tropics in Asia and Africa, and pioneers in underpinning the stability of foraging and agricultural ways of life More targeted research into the two genera would not only cast new light on the proto-agricultural phase of the human story, but be of material benefit to communities who are dependent,

REFERENCES

Aké Assi L, Guinko S. 1996. Confusion de deux taxons spécifiques ou sub-spécifiques au sein du genre *Borassus* en Afrique de l'Ouest. In: Maesen LJG, Burgt XM, Medenbach de Rooy JM (eds) The Biodiversity of African Plants: Proceeding of XIVth AETFAT Congress. Kluwer Academic, Wageningen, The Netherlands. 773-779.

APG IV. 2016. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants. Bot J Linn Soc 181 (1): 1-20.

Asmussen CB, Chase MW. 2001. Coding and noncoding plastid DNA in palm systematics. Amer J Bot 88: 1103-1117.

Asmussen CB, Dransfield J, Deickmann V, Barfod AS, Pintaud J, Baker WJ. 2006. A new subfamily classification of the palm family (Arecaceae): evidence from plastid DNA phylogeny. Bot J Linn Soc 151 (1): 15-38.

Bamualin A, Nggobe M, Malo L. 1990. The influence of mineral block supplements and the starchy pith of *Corypha utan*, (known as 'putak) on the growth of Balinese cattle during the wet season. In: Annual Report of the Livestock Research Sub-Branch at Lili-Kupang, for the Year 1989/1990. Department of Agriculture, Kupang, Nusa Tenggara Timur, Indonesia. [Indonesian]

Banks J. 1971. The Endeavour Journal 1768-1771 (ed Beaglehole JC, 1962). Angus and Robertson, London.

Barfod AS, Banka R and Dowe JL. 2001. Field guide to palms in Papua New Guinea. AAU Reports 40: 1-79.

Barot S, Gignoux J. 1999. Population structure and life cycle of *Borassus aethiopum* Mart.: evidence of early senescence in a palm tree. Biotropica 31: 439-448.

Barot S, Gignoux J, Menaut J. 1999. Demography of a savanna palm tree: predictions from comprehensive spatial pattern analyses. Ecology 80: 1987-2005.

Basu SK, Chakraverty RK. 1987. *Corypha* palms in India. J Econ Taxon Bot 11: 477-486.

Bayton RP. 2005. *Borassus* L. and the Borassoid palms: systematics and evolution. [Dissertation]. University of Reading, UK.

Bayton RP. 2007. A revision of *Borassus* L. (Arecaceae). Kew Bull 62: 561-586.

Bayton RP, Ouédraogo A, Guingko S. 2006. The genus *Borassus* L. (Arecaceae) in West Africa, with a description of a new species from Burkina Faso. Bot J Linn Soc 150:419-427.

Beccari O. 1914. Studio sui *Borassus* e descrizione di un genera nuovo Asiatico di Borassoideae. Webbia 4: 293-385.

Beccari O. 1924. Palme delle Tribù Borasseae. (ed U. Martelli). G. Passeri, Florence, Italy.

Beccari O. 1933. Asiatic palms-Corypheae (ed Martelli U). Ann Roy Bot Gard (Calcutta) 13: 1-356.

Berry WE. 1914. The Upper Cretaceous and Eocene Floras of South Carolina and Georgia. United States Geological Survey Professional Paper 84, Government Printing Office, Washington, USA.

Bhoi P. 2010. Scribe as metaphor: patterns of processing and writing palm leaf manuscripts. Indian Anthropologist 40: 71-92.

Blatter E. 1926. The Palms of British India and Ceylon. Oxford University Press, London.

Bremer K, Janssen T. 2006. Gondwanaland origin of major monocot groups inferred from dispersal-vicariance analysis. Aliso 22: 22-27.

Briggs JC. 2003. The biogeographic and tectonic history of India. J Biogeog 30: 381-388.

Brown WH, Merrill ED. 1919. Philippine Palms and Palm Products. Department of Agriculture and Natural Resources Bureau of Forestry Bulletin No. 18. Manilla, Philippines.

Burkill IH. 1966. A Dictionary of the Economic Products of the Malay Peninsula, Vol. 1. Ministry of Agriculture and Cooperatives, Kuala Lumpur.

Calapis RM, Daracan VC, Castillo SVA, Carandang WM, Abasolo WP. 2011. Structural characterization of buri (*Corypha utan* Lam.) petioles. Philipp J Sci 140: 69-77.

Chang, TT. 1976. Rice: *Oryza sativa* and *Oryza glaberrima*. In: Simmonds NW (ed) Evolution of Crop Plants. Longman, London.

Chevalier A. 1949. Repartition géographique et exploitation des palmiers *Borassus*. Rev Bot Appl Agric Trop 29: 585-592.

Chivas AR, Garcia A, Kaars S, Couapel, MJJ, Holt S, Reeves JM, Wheeler DJ, Switzer AD, Murray-Wallace CV, Banerjee D, Price DM, Wang SX, Pearson G, Edgar NT, Beaufort L, Deckker P, Lawson E, Blaine Cecil C. 2001. Sea-level and environmental changes since the last interglacial in the Gulf of Carpentaria, Australia: an overview. Quatern Intl 83-85: 19-46.

Cook J. 1773. An Account of the Voyages for Making Discoveries in the Southern Hemisphere (ed Hawkesworth J). Vol 3. Strahan W and Cadell T, London

Daghlian CP. 1981. A review of the fossil record of monocotyledons. Bot Rev 47: 517-555.

Dalibard C. 1999. Overall view on the tradition of tapping palm trees and prospects for animal production. Livestock Research for Rural Development. 11 (1): 1-39.

Davis TA. 1988. Uses of semi-wild palms in Indonesia and elsewhere in South and Southeast Asia. Adv Econ Bot 6: 98-118.

Davis TA, Johnson DV. 1987. Current utilization and further development of the palmyra palm (*Borassus flabellifer* L. Arecaceae) in Tamil Nadu State, India. Econ Bot 41: 247-266.

Depommier D. 2003.The tree behind the forest: ecological and economic importance of traditional agroforestry systems and multiple uses of trees in India. Tropical Ecology 44 (1): 62-71.

Dingle H. 2004. The Australo-Papuan bird migration system: another consequence of Wallace's Line. Emu 104: 95-108.

Douglas J, Bimantoro RR. 1957. Identification of the *Corypha* palms which flowered in the Hortus Bogoriensis 1953-1955. Ann Bogor 2: 137-148.

Dowe JL. 2001. Studies in the Genus *Livistona* (Coryphoideae: Arecaceae). [Dissertation]. James Cook University, Townsville, Australia.

Dowe JL. 2010. Australian Palms: Biogeography, Ecology and Systematics. CSIRO Publishing, Collingwood, Vic, Australia.

Dransfield J. 1972. The genus *Borassodendron* (Palmae) in Malesia. Reinwardtia 8(2): 351-363.

Dransfield J. 1981. Palms and Wallace's Line. In: Whitmore TC. (ed) Wallace's Line and Plate Tectonics. Clarendon Press, Oxford. 43-56.

Dransfield J, Beentje HJ. 1995. The Palms of Madagascar. Royal Botanic Garden, Kew, UK.

Dransfield J, Uhl NW, Asmussen CB, Baker WJ, Harley MM, Lewis CE. 2005. A new phylogenetic classification of the palm family, Arecaceae. Kew Bull 60: 559-569.

Dransfield J, Uhl NW, Asmussen CB, Baker WJ, Harley MM, Lewis CE 2008. Genera Palmarum: The Evolution and Classification of Palms. Royal Botanic Garden, Kew, UK.

Ferguson W. 1850. The Palmyra Palm. Observer Press, Colombo.

Ferguson IK, Havard AJ, Dransfield J. 1986. The pollen morphology of the tribe Borasseae (Palmae: Coryphoideae). Kew Bull 42: 405-422.

Fox JJ. 1977. Harvest of the Palm: Ecological Change in Eastern Indonesia. Harvard University Press, Cambridge, Massachusetts.

Frith DW, Frith CB. 1995. Cape York Peninsular: A Natural History. Reed Books, Chatswood, Australia.

Gebius L, Abdul Kadir R. 1929. Enkele gegevens omtrent den siwalan op Madoera. Lambouw (Buitenzorg, Java) 4: 304-321.

Gignoux J, Barot S, Menaut J, Vuattoux R. 2007. Structure, long-term dynamics, and demography of the tree community. In: Abbadie L, Gignoux J, Le Roux X, Michel Lepage M (eds). Lamto: Structure, Functioning, and Dynamics of a Savanna Ecosystem. Ecol Stud 179: 335-364.

Ginting-Moenthe U, Chakeredza S, Meulen U ter. 2002. The influence of fermented putak on diet digestibility and growth performance of weanling pigs. Anim Feed Sci Technol 102: 217-214.

Glover I. 1986. Archaeology in Eastern Indonesia, 1966-1967. Australian National University, Canberra, ACT.

Griffith W. 1850. Palms of British East India. Charles A. Serrao, Calcutta.

Hahn WJ. 2002. A molecular phylogeny study of the Palmae (Arecaceae) based on atpB, rbcL, and 18S nrDNA sequences. Syst Biol 51: 92-112.

Hardrave RL. 1969. The Nadars of Tamilnad: The Political Culture of a Community in Change. University of California Press, Berkeley.

Harley MM. 2006. A summary of fossil records for Arecaceae. Bot J Linn Soc 151: 39-67.

Henderson A. 2009. Palms of Southern Asia. New York Botanical Gardens, Princeton University Press, Princeton, New Jersey.

Heyne K. 1927. De Nuttige Planten van Nederlandsch-Indië, 2nd ed. 3 Vols. Buitenzorg Departtement van Landbouw, Nijverheid en Handel in Nederlands-Indie. Martinus Nijhoff, The Hague.

Hinzler HIR. 1993. Balinese palm-leaf manuscripts. Bijdragen tot de Taal-, Land-en Volkenkunde 149 (3): 438-473.

Horn JW, Fisher JB, Tomlinson PB, Lewis CE, Laubengayer K. 2009. Evolution of lamina anatomy in the palm family. Amer J Bot 96: 1462-1486.

IUCN 2016. The IUCN Red List of Threatened Species. www.iucnredlist.org

Janssen T, Bremer K. 2004. The age of major monocot groups inferred from 800+ rbcL sequences. Bot J Linn Soc 146: 385-398.

Johnson, D. 1998. *Corypha taliera*. The IUCN Red List of Threatened Species. www.iucnredlist.org/details/full/38493/0

Jones R, Meehan B. 1989. Plant foods of the Gidjingali: ethnographic and archaeological perspectives from northern Australia on tuber and seed

exploitation. In: Harris DR, Hillman GC (eds) Foraging and Farming: the Evolution of Plant Exploitation. Unwin Hyman, London.

Jumelle HL, Perrier de la Bâthie H. 1913. Palmiers de Madagascar. Ann Mus Colon Marseille, sér 3. 1: 1-91.

Khieu Borin. 1996. The sugar palm tree as the basis of integrated farming systems in Cambodia. Livestock Feed Resources within Integrated Farming Systems, Second FAO Electronic Conference on Tropical Feeds, 9 September 1996 - 28 February 1997, FAO, Rome. www.fao.org/livestock/agap/frg/conf96.pdf/khieu.pdf.

Kondo T, Crisp MD, Linde C, Bowman DMJS, Kawamura K, Kaneko S, Isagi Y. 2012. Not an ancient relic: the endemic *Livistona* palms of arid central Australia could have been introduced by humans. Proc R Soc B 279: 2652-2661.

Kovoor A. 1983. The Palmyrah Palm: Potential and Perspectives. FAO Plant Production and Protection Paper. No. 52. FAO, Rome.

Kovoor A, Hussein NN. 1983. Taxonomy and phylogeny of palms based on restriction-enzyme analysis of the DNA of the chloroplast DNA. Lesser Known Palms of Tropical America. FAO consultation Turrialba.

Lamarck JBAPM. 1786. Encyclopédie méthodique. Botanique 2: 130-131.

Latifah D, Congdon RA, Holtum JA. 2014. A physiological approach to conservation of four palm species: *Arenga australasica*, *Calamus australis*, *Hydriastele wendlandiana* and *Licuala ramsayi*. Reinwardtia 14: 237-247.

Lecomte H. 1917. Observations sur les feuilles d'un Corypha de l'Indo-China. Bull Soc Bot France 63: 79-84.

Liddle D., Russell-Smith J, Brock J, Leach GJ, Connors GT. 1994. Atlas of the Vascular Rainforest Plants of the Northern Territory. Flora of Australia Supplementary Series, No. 3. Australian Biological Resources Study, Canberra, ACT.

Linnaeus C. 1753. Species Plantarum, Impensis Laurentii Salvii. Stockholm, Sweden.

Lubeigt G. 1982. Une civilization du palmier à sucre en Asie. Le Courrier du CNRS. 44: 24-35.

Martius CFP von. 1838. Historia Naturalis Palmarum, Vol 3. Weigel TO, Leipzig, Germany.

McLoughlin S. 2001. The breakup history of Gondwana and its impact on pre-Cenozoic floristic provincialism. Aust J Bot 9: 271-300.

Metcalfe I. 2002. Tectonic history of the SE Asian-Australian Region. In: Kershaw P, Bruno D, Tapper N, Penny D, Brown J (eds) Bridging Wallace's Line: The Environmental and Cultural History and Dynamics of the SE-Asian-Australian Region. Adv Geoecol 34: 29-48.

Mogea J, Seibert B, Smits W. 1991. Multipurpose palms: the sugar palm. Agroforestry Systems 13: 111-129.

Mogea JP. 2004. Four new species of *Arenga* (Palmae) from Indonesia. Reinwardtia 12: 181-189.

Ormeling FJ. 1956. The Timor Problem: A Geographical Interpretation of an Undeveloped Island. JB Wolters, Jakarta, Indonesia.

Padmanbhan D, Pushpa Veni S, Gunamani M, Regupathy D. 1978. Tuberous Seedlings of *Borassus flabellifer*. Principes 22: 119-126.

Paulas D, Muthukrishnan CR. 1983. The situation of Palmyrah in India. FAO/ DANIDA Palmyrah Workshop, Jaffna, Sri Lanka.

Portères R. 1964. Le palmier rônier (*Borassus aethiopum* Mart.) dans la province du Baoule (Côte d'Ivoire). J Agric Trop Bot Appl 11: 499-516.

Prebble M, Sim R, Finn J and Fink D. 2005. A holocene pollen and diatom record from Vanderlin Island, Gulf of Carpentaria, lowland tropical Australia. Quatern Res. 64: 357-371.

Pudjoarinto A. 1982. Taxonomic Study of Siwalan (*Borassus flabellifer* L.) found in Java and Madura. [Dissertation]. Gadjah Mada University, Yogyakarta. [Indonesian]

Rheede tot Drakenstein HA. 1678. Hortus Indicus Malabaricus, Vol 1. Amsterdam.

Roxburgh W. 1820. Plants of the Coast of Coromandel 3: 51.

Roxburgh W. 1832. Flora Indica: Descriptions of Indian plants. 2nd ed. (ed Carey W). Vol. 2. Serampore, India.

Rukan S, Suwanwaree P. 2010. Inflorescence growth of *Corypha lecomtei* in Tab Lan National Park. The 4th Botanical Conference of Thailand, March 24-26, Chiang Mai, Thailand.

Rukan S, Triwitayakorn K, Suwanwaree P. 2010. Genetic diversity and variation among Thai *Corypha* populations as revealed by AFLP markers. The International Conference on Biodiversity of Southern Thailand. Nakhon Si Thammarat, Thailand.

Rumphius GE. 1741. Herbarium Amboinense 1. J Burmann, Meinard Uytwerf, Amsterdam.

Sambou B, Goudiaby A, Ervik F, Diallo D, Ciré Camara M. 2002. Palm wine harvesting by the Bassari threatens *Borassus aethiopum* populations in north-western Guinea. Biodivers Conserv 11: 1149-1161.

Sastrapradja DS, Davis TA. 1983. The Bogor Botanic Garden and its rich collection of palms. Principes 27 (1): 18-30.

The Buri Bag Project. 2016. www.theburibagproject.com

Tjitrosoepomo G, Pudjoarinto A. 1983. Studies on Palmyrah (*Borassus flabellifer* L.) in Indonesia. FAO/DANIDA Palmyrah Workshop, Jaffna, Sri Lanka.

Tomlinson PB. 1961. Palmae. In: Metcalfe CR. (ed). Anatomy of the Monocotyledons. Clarendon Press, Oxford, UK.

Tomlinson PB, Jeffrey EC. 1990. The Structural Biology of Palms. Clarendon Press, Oxford, UK

Tomlinson PB, Horn JW, Fisher JB. 2011. The Anatomy of Palms: Palmae-Arecaceae. Oxford University Press, Oxford, UK.

Uhl NW, Dransfield J. 1987. Genera Palmarum: A Classification of Palms based on the Work of HE Moore Jr. LH Bailey Hortorium/International Palm Society. Allen Press, Lawrence, Kansas.

Uhl NW, Dransfield J, Davis JI, Luckow MA, Hansen KS, Doyle JJ. 1995. Phylogenetic relationships among palms: cladistics analyses of morphological and chloroplast DNA restriction site variation. In: Rudall PJ, Cribb PJ, Cutler DF, Humphries CJ (eds) Monocotyledons: Systematics and Evolution. Royal Botanic Gardens, Kew. 623-661.

Umar MB, Fuah AM, Bamualin A. 1991. The effect of rations combining different levels of 'putak' (the starchy pith of *Corypha utan*) and corn on the growth and egg production of free range chickens. In: Research Results of the Livestock Research Sub-Branch at Lili-Kupang, for the Year 1990/1991. Department of Agriculture, Kupang, Nusa Tenggara Timur, Indonesia. [Indonesian]

Vannan G. 2011. Toddy politics heats up in Tamil Nadu. The New Indian Express, 17 Jan 2011, www.newindianexpress.com/states/tamil_nadu/article407739.ece.

Veevers JJ. 1991. Phanerozoic Australia in the changing configuration of proto-Pangea through Gondwanaland and Pangea to the present dispersed continents. Aust Syst Bot 4: 1-11.

Walter Scott DJ. 2014. Palm tree climbers sweat it out in a 'dying' trade. The Hindu National Tamil Nadu, 14 Jul 2014. www.thehindu.com/news/national/tamil-nadu/palm-tree-climbers-sweat-it-out-in-a-dying-trade/article6206940.ece.