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# Holocene landscape intervention and plant food production strategies in island and mainland Southeast Asia<sup>☆</sup>



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## ABSTRACT

In the areas adjacent to the drowned Pleistocene continent of Sunda – present-day Mainland and Island SE Asia – the Austronesian Hypothesis of a diaspora of rice cultivators from Taiwan ~4200 years ago has often been linked with the start of farming. Mounting evidence suggests that these developments should not be conflated and that alternative explanations should be considered, including indigenous inception of complex patterns of plant food production and early exchange of plants, animals, technology and genes. We review evidence for widespread forest disturbance in the Early Holocene which may accompany the beginnings of complex food-production. Although often insubstantial, evidence for incipient and developing management of rainforest vegetation and of developing complex relationships with plants is present, and early enough to suggest that during the Early to mid-Holocene this vast region was marked by different approaches to plant food production. The trajectory of the increasingly complex relationships between people and their food organisms was strongly locally contingent and in many cases did not result in the development of agricultural systems that were recognisable as such at the time of early European encounters. Diverse resource management economies in the Sunda and neighbouring regions appear to have accompanied rather than replaced a reliance on hunting and gathering. This, together with evidence for Early Holocene interaction between these neighbours, gives cause for us to question some authors continued adherence to a singular narrative of the Austronesian Hypothesis and the 'Neolithisation' of this part of the world. It also leads us to suggest that the forests of this vast region are, to an extent, a cultural artefact.

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## 1. Introduction

This paper deals with evidence for regimes of Holocene landscape management and food production in the lands around the Sunda Shelf – Mainland and Island SE Asia (Fig. 1). Where, in many parts of the globe, the phrase 'the transition to farming' and the term 'Neolithic' imply one of the great transitions in prehistory, in the study area these terms are less germane and a different model may be more appropriate.

In Europe, Southwest Asia and adjoining regions, the Early Neolithic is the time when hunting and gathering economies were replaced (through a variety of mechanisms) by economies based on farming, with a small initial 'package' of cereal crops (wheat, barley, oats) joined through most of its dispersal by domesticated animals

(cattle, sheep/goats, pigs) (Barker, 1985; Bellwood, 2005). This change was accompanied by profound reorganisations of society and material culture and thus is regarded as one of the great discontinuities in human prehistory. It was visible as a significant event to researchers very early in the development of archaeology – Gordon Childe (1925, 1934) dubbed it the 'Neolithic Revolution'. The spread of Neolithic farming in Europe appears to have been accompanied by a certain level of relocation of genetic groups (e.g. Cavilli-Sforza et al., 1988; Richards, 2003; Soares et al., 2010). Suggested changes in population density may perhaps have been mediated by the differences in carrying capacity between foraging and farming systems. These were interpreted by some as a 'push-factor' that would fuel the spread of population and economic systems (Bellwood and Renfrew, 2002; although see recent discussions of these models, e.g. Zeder, 2012). The ability to generate a storable food surplus enabled the development of more complex societies and craft specialisations impossible in hunting and gathering economies in these regions.

A similar pattern of Neolithic spread, with movement of crops and genetic material, has been asserted for other parts of the world

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**Fig. 1.** Location of Early Holocene sites reviewed in [Table 1](#).

(Bellwood and Renfrew, 2002; Bellwood, 2005). One powerful example of the application of European-influenced Neolithic models has been the ‘Austronesian Hypothesis’ (e.g. Bellwood, 1985, 1988, 1997, 2005, 2011; Diamond, 2001; Diamond and Bellwood, 2003; Spriggs, 2011) where apparently convergent linguistic and archaeological evidence was interpreted to indicate a diaspora of Austronesian-speaking, rice-growing agricultural people from Taiwan some 5000 years ago. These people are argued to have spread across many of the islands of the Sunda Shelf – the great archipelago of Island Southeast Asia (Fig. 1), acquiring tree crops and losing rice on the way, before dispersing further to

Madagascar and across the Pacific Islands. The hypothesis has been very persuasively argued, has considerable explanatory power and has been extremely influential. There is no doubt that there is a cogent and factual basis to the argument: many peoples across a vast region of the Earth’s surface share cognate languages and genetic material, and the archaeological footprint of the early inhabitants of most of the Pacific islands, with characteristic artefacts, including pottery, is also incontrovertible.

It has been argued, however, (Terrell et al., 2001; Donohue and Denham, 2010; Blench, 2010; Barker and Richards, 2012) that the coherence and strong explanatory power of this narrative have led

to the eclipse of earlier views of the prehistory of the region including the 'Nusantao Hypothesis' of Solheim (1984) and have subsequently channelled and constrained debate about other interpretations of the evidence. Solheim (1984) had argued that people living on the emergent Sunda Shelf in the Early Holocene were forced by sea-level rise to become maritime, and that marine interaction would have led to linguistic and cultural similarities such as the 'Kalnay' ceramic tradition and the exchange of agricultural resources.

Amongst others, Terrell et al. (2001), Donohue and Denham (2010) and Denham (2013) argue that the experience of the archaeological community in Europe and Southwest Asia had shaped expectations and discourses in mainland and island Southeast Asia, where events had been seen through the lens of a Eurocentric group of concepts and assumptions. They argue – as have others since Gorman (1970, 1971) – that the lens of ideas generated from events in European prehistory should not be used uncritically to examine developments in other areas.

In the last ten years, emerging genetic, linguistic and archaeological/palaeobotanical evidence (for instance Paz, 2002; Barton and Paz, 2007; Soares et al., 2008, 2011; Bulbeck, 2008; Blench, 2010; Denham et al., 2009a,b; Donohue and Denham, 2010, 2011; Barker et al., 2011; Barker and Richards, 2012; Denham, 2013) suggests that alternative interpretations may have currency in the wider region. Here we review indications of change in landscape management and food production strategies during the Holocene across the vast area of Island and mainland Southeast Asia (hereafter, 'the region' or 'the lands around the Sunda rim'). At first Western contact, a huge range of strategies existed and many persist in modern times. Many of these are intimately bound up with sophisticated systems of forest management (Wiersum, 1997) and resource use and it is becoming possible to suggest they have an extensive and important prehistoric ancestry in the region (Rabett, 2012).

## 2. The beginnings of forest management in the region

It is argued here that there is a relatively long prehistory to land management practices in the region, as is now also becoming apparent in neighbouring Sahul (the biogeographic region encompassing the easternmost Indonesian islands, New Guinea and Australia). Pollen, charcoal and archaeology suggest that repeated biomass burning to produce productive forest-edge environments seems to have appeared ~50,000 years ago, shortly after the arrival of the first modern human populations (Hope, 1998, 2009; Haberle, 1998; van der Kaars et al., 2000; Hunt et al., 2007, 2012; Summerhayes et al., 2010; Lentfer et al., 2010), although Kershaw et al. (1997) and van der Kaars et al. (2001) suggest an approximate date of ~65,000 years for the beginning of biomass burning in Java. Regular fire in Late Pleistocene savannahs is suggested in NE Thailand by Penny (2001) and during the latest Pleistocene in grassy vegetation at low altitude in West Java by van der Kaars et al. (2001). In both cases, though, it is unclear whether this reflects human activity.

## 3. Traditional forest management and cultivation in the region

It was an assumption – almost an article of faith – amongst many biogeographers, ecologists and palaeoecologists that the great regional rainforests were, at Western contact, the product of natural climatic, biogeographic and ecological processes (e.g. Flenley, 1979; Morley, 2000). It was widely thought that peoples living in the rainforest caused little change to vegetation outside localised areas of 'slash and burn'. This is implicit also in

anthropological debates about the viability of pure forager lifestyles in lowland tropical forests (e.g. Headland, 1987; Hutterer, 1988; Bailey et al., 1989; Townsend, 1990; Bailey and Headland, 1991; Dentan, 1991).

This stereotype seems to be far from the case: the truly vast extent of 'well-worked' secondary forest in Borneo was first noted by Gibbs (1914) and more recent development and anthropological work documents the widespread and highly variable nature of systems of forest management (e.g. Kedit, 1982; Wiersum, 1997; Sellato, 2001; Latinis, 2000; Janowski, 2004). Although it is evident that these practices were very widespread at first Western contact in the region, their antiquity is uncertain.

A number of points are germane to any understanding of the human use of plants and animals in the region. These include an extremely diverse range of activities, the nature of the economically useful plants (many of which are perennial) and thus the timescales involved in propagation and cultivation systems, the general lack of plant cultivars clearly separated genetically from wild ancestors and the lack of locally-domesticated animals.

### 3.1. Typology of activity

In the traditional European perspective originating with Childe (1925, 1934), we have a clear typology of 'foragers' and 'farmers'. Although it is readily acknowledged that even today many farmers worldwide might hunt a little and gather the odd wild plant food, the opportunities for this were limited outside the initial period of the expansion of agriculture (however protracted this was – see for instance Gregg, 1988 for an instance of this initial period taking ~2000 years in Germany). This is simply because the loss of habitat to farming made rare very many wild food organisms. It is otherwise in many of the lands around the Sunda rim, where outside intensive rice-growing areas and modern industrial plantations a very complex situation still obtains. There is, for a start, an extremely wide range of traditional practices of management, manipulation and exploitation of forest resources. These grade into true arboriculture and include clan forests, catchment protection forests, temple forests and sacred groves, taboo and protected trees, species-enriched forests, enriched fallows, forest gardens, small-holder plantations and home gardens (Kedit, 1982; Brosius, 1991; Wiersum, 1997; Latinis, 2000; Salafsky, 1994; Mulyoutami et al., 2009; see also Kennedy, 2012 for similar instances in Sahul). Until very recently in Borneo, most farmers obtained meat by hunting because there were no domesticated animals – this is still the case today with traditional groups such as the Kelabit (Janowski, 2004). Further, even groups such as the Kelabit, who recognise themselves as farmers, still gather many wild or semi-wild plant foods and manage the forest. They recognise and maintain as 'Womens' Forest' areas of secondary forest, regenerating abandoned fields and places where fruit trees were planted on the sites of abandoned long-houses. In these places women gather fruit, together with edible ferns, leafy plants and fungi. Rotan palms (*Calamus* spp.) for basketry are also gathered from places in the secondary forest (Janowski, 2004). Men hunt in areas of old-growth woodland distinct from the 'Womens' Forest'. On the other hand, the Penan, a group that see themselves and are perceived as purely foragers, actually also participate in forest management by planting seeds of the sago palm in favourable locations (Kedit, 1982; Brosius, 1991) and in some circumstances controlling other vegetation in order that the sago palms thrive. Finally, the tropical environment leads to problems for cultivators. Monocultures typically become rapidly overcome by weeds unless rigorously weeded and bare soil washes away rapidly (Kenzo et al., 2010; Anda and Kurnia, 2010; Valentin et al., 2008), so a characteristic traditional way of growing many food plants is in polyculture, often among trees (Salafsky, 1994;

Mulyoutami et al., 2009). Thus, it is fair to say that the distinctions between 'wild' and 'cultivated' plants, or between 'foraging' and 'farming' lifestyles would be at best blurred and at worst meaningless to many people in the lands around the Sunda rim.

### 3.2. Domestication

As noted above, in the lands around the Sunda Shelf, the distinction between 'cultivated' and 'wild' was (and often still is) blurred. People such as the Penan will at times select and propagate wild plants in the forest (Kedit, 1982; Brosius, 1991) and other groups will incorporate wild plants into their plots. There is difficulty in preventing genetic mixing between these selected forms and immediately-adjacent wild populations. The characteristic modifications to food plants for taste and manageability which we call 'domestication' did not occur widely, with the notable exception of the hybridisation which led to the modern banana (Carreel et al., 2002; Perrier et al., 2011) and the appearance of sterile clones of the yam (Lebot et al., 2004; Malapa et al., 2005). Moreover, the sheer variety of plants in the diet (Christensen, 2002) means that few are of overwhelming importance and thus less likely selectively bred. The Barawan, for instance, claim to gather fruit from a different species from the genus *Sapindus* for every month of the year (COH, pers. obs., 2004) and this genus is only a tiny proportion of their diet. Further, domestication of the native fauna hardly occurred so wild meat remained an important resource.

### 3.3. The nature of the edible plants

The vast majority of indigenous food plants in the region are herbaceous (either leafy or tuberous) or are trees (Dewar, 2003; Barton and Paz, 2007; Barton and Denham, 2011). Although several species of wild rice are indigenous and some were most probably exploited (e.g. Kealhofer, 2002; Barker et al., 2011), domesticated rice was introduced, probably ~4000 BP when it appears in pottery at Gua Sireh (Bellwood et al., 1992) then a little later at Niah (Doherty et al., 2000). This has a number of implications. For the tuberous and herbaceous crops, harvest is rarely concentrated into a single season. Many fruits do have distinct seasons, but (as noted above for *Sapindus* spp.), there are fruit species ripening throughout the year. Further, storage (other than short term storage of root crops in the ground) and long-distance transport of many plant foods was not possible and thus precluded the accumulation of surpluses.

### 3.4. Timescales of activity

Timescales of activity are controlled by the phenology of the food plants. Tree crops typically take many years to mature and become productive (Mulyoutami et al., 2009). One of the authors (COH) recalls meeting a Punan man gathering fruit beneath some huge trees on the heavily-forested riverbank of the Sungai Niah in the Niah National Park, Sarawak, in 2001. He told us "These are my grandfather's trees: he planted them for me and just now they start to give fruit". Many indigenous root crops also need a cropping cycle more than a year-long (Dewar, 2003).

All of these factors combine to produce patterns of human activity and plant occurrence extremely different from those present in agricultural systems in much of the world. There is a continuum, in practice, between 'wild' ecosystems relatively unaffected by human intervention, through various types of augmented and secondary forest, forest gardens, cultivation plots and fields (Wiersum, 1997) and parts of this spectrum may have a considerable prehistory (below). For parts of this spectrum, there are close comparisons with the better-known Holocene systems of New

Guinea (for instance Denham et al., 2003, 2009a,b; Denham, 2004, 2009, 2011, 2013; Denham and Haberle, 2008; Kennedy, 2012; Haberle et al., 2012) where often-related plants and techniques were used.

## 4. Rainforest use and the palynological signal

It is extremely difficult to recognise the archaeological signature of past human activity in tropical environments because much it seems to have involved perishable materials with few or no stone and ceramic artefacts. Highly-visible stone structures appeared only in the last few millennia. Further, dense vegetation and litter layers make ground survey difficult and thick tree canopies limit aerial exploration (Hunt et al., 2012).

A common approach to recognise human activity elsewhere is to decode palaeoenvironmental records for anomalies indicative of human activity. Many palynologists working in the region have suggested that human activity is visible in their records (see for instance. Maloney, 1980, 1999; Newsome and Flenley, 1988; Kealhofer and Penny, 1998; Flenley and Butler, 2001; Maxwell, 2001, 2004; White et al., 2004; Hunt and Rushworth, 2005; Hunt and Premathilake, 2012), usually because palynological records contain episodes characterised by pollen of disturbance indicators and abundant microscopic charcoal. The approach of examining records for disturbance indicators and charcoal is analogous to the approach used by palynologists to identify the Neolithic in temperate latitudes (see, for instance authors cited in Whitehouse et al., 2014). This information has rarely been examined systematically on a regional scale, however, except for the synthesis for Thailand by Kealhofer (2002) and wider discussion by Maloney (e.g. Maloney, 1998).

This approach is likely to produce a signal in relatively stable conditions in the middle and later Holocene. There is, however, considerable difficulty in differentiating anthropogenic clearance activity from natural fire caused by lightning strike unless pollen of cultivars or some other form of distinctive evidence such as phytoliths is present, or if archaeological evidence contemporary with the disturbance is present nearby. Unfortunately, few cultivated taxa in the region produce distinctive pollen. In this case, only pollen of taxa outside their geographical area of origin can be accepted as propagated by humans.

In the earlier literature, microscopic 'charcoal' was often taken as evidence for fire and this in turn is often interpreted as a marker for human disturbance of ecosystems. This is, of course, problematic (see for a critique Penny and Kealhofer, 2005 and recent discussions of charcoal analysis e.g. by Whitlock and Larsen, 2007). Selective vegetation modification by fire does not necessarily require big extensive fires – observation of a shifting cultivator in Niah National Park in 2002 by COH showed him using very small fires to burn through individual buttress roots of a mature forest tree until it fell. The procedure produced remarkably little smoke and charred wood. By no means all microcharcoal has an anthropogenic origin, as fire plays a natural part in many tropical ecosystems, particularly during droughts (Goldammer and Seibert, 1989), and is often associated with El Niño (Maxwell, 2004). Further, 'microcharcoal' is not just generated by fire. Thermally mature (charred) matter of all types is highly durable even in tropical environments and material of geological origin may be liberated from sedimentary bedrock or old soils by erosion (Hunt et al., 2012).

The nature of the wild edible economically-useful and cultivated plants discussed above also has implications for the palynologist and palaeobotanist. Because the cultivated plants were still mostly morphologically indistinguishable from wild relations, using the occurrence of characteristic cultivated plant morphologies, as is



done in many parts of the world, to distinguish economic activity and particularly cultivation *per se* is next to impossible. The position is exacerbated because in many traditional cultivation systems wild foods are still important. Furthermore, some plants are palynologically invisible: for instance many yams do not often produce pollen and bananas produce pollen which does not preserve.

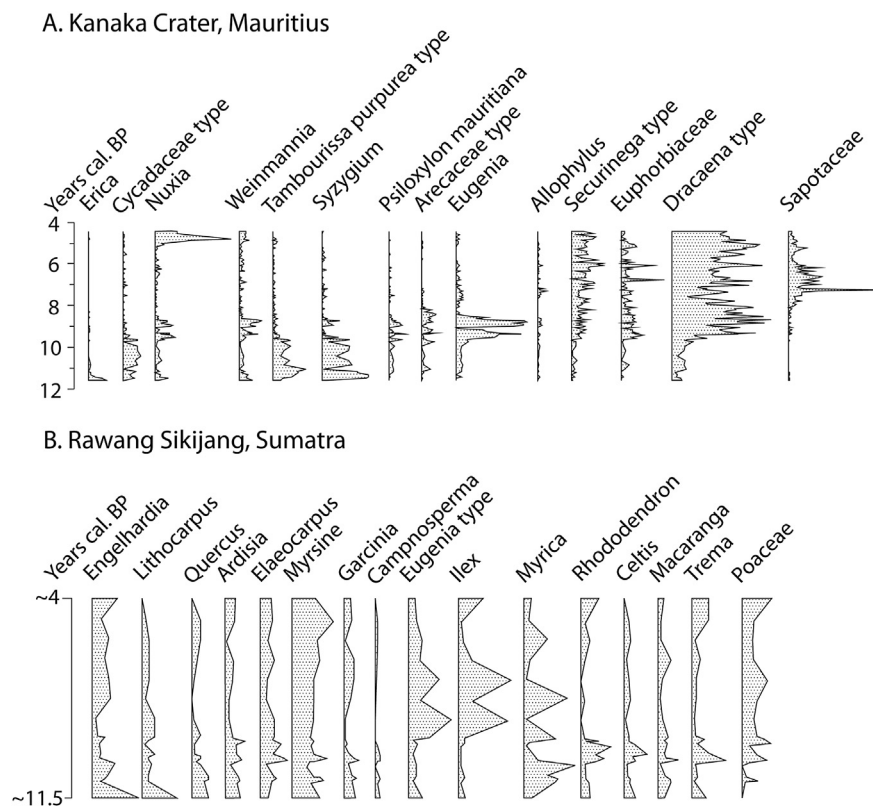
### 5. Using interrupted successions to identify human activity in the Early Holocene

Patterns of anthropogenic activity in tropical forest ecosystems may also be recognised by contrasting the palaeoenvironmental record with well-understood models of vegetation change and particularly with the signal from natural successions, unaffected by human intervention. It is a contention of this paper that natural Early Holocene successions are rather rare in the lands around the Sunda rim, except in places where people are most likely to have avoided, such as the hydrosere successions of the great raised mires. The raised mires (e.g. Anderson, 1963; Anderson and Muller, 1975; Page et al., 1999, 2004) characterise much lowland terrain and are characterised by very low nutrient status, with both animal and plant food resources for humans very sparsely available.

A good example of the type of Holocene succession that might be expected without human intervention in the region is given by de Boer et al. (2013) for montane forest in the very-isolated island of Mauritius, which has no Early Holocene archaeology. There, Late Pleistocene assemblages are characterised by *Nuxia*, *Weinmannia*, *Tambourissa purpurea*, *Erica*, and *Cycadaceae*, with *Syzygium*, *Pilea/Ficus* type, *Artemisia*, and *Pandanus*. At 11,500 cal. BP, *Artemisia* disappeared and *Erica* became rare. *Syzygium*, *Psiloxylon mauritianum* and *Cycadaceae* became briefly important, with some

*Cyathea*, *T. purpurea*, *Allophylus* and *Olea* present. At 9600 cal. BP, *Cycadaceae* and *Syzygium* became rare and are succeeded by *Eugenia*, *Dracaena* type and *Securinega* type, with *Arecaceae*, *Pandanus*, *Psiloxylon*, *Nuxia* and *Weinmannia* and some *Aphloia*, *T. purpurea*, *Allophylus*, *Molinaea* and *Sapindaceae*. At 8500 cal. BP, *Eugenia*, *Nuxia* and *Weinmannia* became rare, *Pandanus* declines and *Sapotaceae* expand (de Boer et al., 2013). In this tropical forest, taxa follow one another in dominating the environment as a response to changing temperature and rainfall and to the dynamics of inter-species competition. This type of changing species dominance – a climatically-driven succession (Fig. 2A) – is familiar to palaeoecologists studying the Early Holocene over much of the planet.

As such, one way to test for the presence of human intervention in the forests around the Sunda rim would be to log the extent of disrupted successions and of climatically-driven successions during this period. If a climatically-driven succession is present, this would imply that natural processes were not constrained by human activity. The alternative would be that humans were disrupting natural succession through burning and other activities, as has been suggested at Loagan Bunut in Borneo. At that site, located ~40 km inland from the shores of the South China Sea, the 40 m core commences at ~11,200 cal. BP and contains no recognisable climatically-driven succession (Hunt and Premathilake, 2012). Disturbance indicators and abundant charred organic matter are present from the base of the profile. Pollen from sago palms is present from the outset and the eastern Indonesian/New Guinea sago palm *Metroxylon* appears from ~10,400 cal. BP, leading one to suppose the import of this species and that sago was being propagated. This may have been no more than the ‘plant and leave’ practised today by some Penan groups (Kedit, 1982), or possibly it was more akin to a form of active management, such as that



**Fig. 2.** Typical early Holocene pollen diagrams. A., Kanaka Crater, Mauritius, showing a clear early Holocene succession, with a sequence of taxa dominating the vegetation (after de Boer et al., 2013). B., Rawang Sikijang, Sumatra, with a disrupted succession with the disturbance indicators *Celtis*, *Macaranga*, *Trema* and *Poaceae* common from the base of the Holocene and expanding ~8 ka BP (after Fleinley and Butler, 2001).

recorded by Kennedy (2012). Other sago species occurring later in the Early Holocene at Loagan Bunut include *Caryota* (which according to Penan informants interviewed by Kedit (1982: 257) provides the most desirable sago) and the sugar palm *Arenga*. Given that some form of arboriculture using *Metroxylon* was occurring, it is at least conceivable that the system also incorporated the other sago species, particularly as *Eugeissona* was outside its normal lower montane forest range in Borneo, thus seeming to imply human intervention. There are other economically-useful taxa in the Loagan Bunut record, including *Areca*, *Mangifera*, Cucurbitaceae and *Murraya* cf. *paniculata*, but whether they were propagated, or indeed utilised, cannot be demonstrated from present evidence. Also present throughout the sequence are very abundant rice phytoliths, many of which are burnt (Barker et al., 2011). Given the taxonomic uncertainty surrounding rice phytoliths, it is by no means clear which of the species of rice was present (the morphological variation would suggest that possibly two species were present), but the fact that they are consistently very abundant and that many are burnt might suggest that part of the land management strategy of the people at Loagan Bunut may have involved some maintenance of open areas on the low-salinity fringes of the estuary by regular burning, presumably to exploit stands of wild rice. This type of activity chimes with the patterns seen in the Early Holocene in the Yangtze Delta in China, where fire was used to maintain stands of rice (Zong et al., 2007; Innes et al., 2010; Shu et al., 2010). Burning, forest disturbance, pollen of sago palms and rice phytoliths persist at Loagan Bunut until sedimentation ended a little after ~7000 cal. BP (Hunt and Premathilake, 2012), suggesting that this was a long-lived and stable system of land management, which must have been at least partly for food production.

These data support our proposition that disruption of Early Holocene successions can serve as a favourable proxy for human intervention in rainforest habitats of this region. A full survey of pollen diagrams of Early Holocene age is given in Table 1. This shows that in some areas, for instance Sumatra, lowland West Java, Borneo and Vietnam, there is clear evidence that natural successions were repeatedly disrupted. The disrupted successions are usually accompanied by high incidences of disturbance indicators (typically Poaceae, *Macaranga*, *Mallotus*, *Trema*, *Celtis*, Compositae – see for example the ecological work of Slik et al., 2003, 2008). These are present close to the base of the Holocene at some localities, but at other places they appear later. This is very apparent in Sumatra (Table 1; Fig. 2B), where disruption starts at ~10,500 at Tao Sippinggan (Maloney, 1996), then at ~9600 cal. BP at Danau Padang (Morley, 1982), around ~8000 cal. BP at Rawang Sikijang (Flenley and Butler, 2001) and Pea Sim-Sim (Maloney, 1980), but not until ~7500 cal. BP at Pea Bullok (Maloney and McCormack, 1996; Maloney, 1996). This general pattern might be expected as human activity spread out over time but does not chime well with an alternative hypothesis of climate-driven fire disruption of forest. At some locations, however, disruption does not occur, and/or disturbance indicators appear very late (e.g. Maxwell, 2001, 2004).

Indications of the economically-useful taxa associated with these disturbances to successions are, however, rarely evident apart from at Loagan Bunut. In the Kelabit Highlands, Borneo, pollen of the sago palm *Caryota* and possible fruit trees including Sapindaceae, Sapotaceae and *Callicarpa* are associated with canopy disturbance ~6400 cal. BP (Jones et al., 2013a,b). Jones et al. (2013a,b) suggest that taros and yams, which do not yield diagnostic pollen or phytoliths, could also have been cultivated, a suggestion that chimes with the work of Barton and Paz (2007). These were already in use in the region, as attested by evidence from the Late Pleistocene, for example, at the Niah Caves, Borneo (Paz, 2005; Barton, 2005). At Ille Cave in the Philippines, there is evidence for very early Holocene use of a yam indistinguishable morphologically

from the cultivated *Discorea alata* from contexts approximately 10,000 years old, while taro was found in a 9500 year-old layer, although it is not clear whether this was a wild or cultivated form (Barker et al., 2011). It is plausible, but currently impossible to demonstrate, that use of these tuberous plants was very widespread indeed in the region.

## 6. Comparative evidence from Sahul

Corroborating the evidence discussed above are similarly early systems of landscape management and food production in Sahul, to the south of the region dealt with in this paper. There is good evidence for marine interconnection between Sahul and the lands around the Sunda Shelf (below).

It has become abundantly apparent in recent years that there was a separate origin for agriculture in upland New Guinea, with subsistence based on tubers and tree crops. This is known from the pioneering work of Golson (e.g. 1977, 1991), Golson and Hughes (1980), Bayliss-Smith (1996) and the remarkable research of Tim Denham and his co-workers (e.g. Denham et al., 2003, 2004, 2005, 2007, 2009a,b; Denham, 2004, 2009, 2011, 2013; Denham and Barton 2006; Fullagar et al., 2006; Denham and Haberle, 2008; Haberle and David, 2004; Haberle et al., 2012).

At Kuk Swamp, during the early Holocene, there was increasingly intensive management of plants and the processing of taro and yam, both plants that may have originated in lowland environments (Denham et al., 2003, 2004; Denham and Haberle, 2008; Haberle et al., 2012; Fullagar et al., 2006). Stake holes, pits and other features thought to relate to planting and ‘tethering’ of plants are reported from 8000 years ago (Denham, 2004). By 7000 years ago, widespread clearance and the creation of mounds for cultivation of tuberous plants appear to mark the nascent development of an agricultural landscape on a regional scale (Denham and Haberle, 2008; Haberle et al., 2012) with cultivation of bananas, taro, yams and sugarcane (Denham et al., 2003). The archaeological and palaeoecological evidence points to further intensification and landscape degradation over the following millennia (Denham, 2004; Denham, 2004, 2009, 2011; Fullagar et al., 2006; Denham and Haberle, 2008). This activity is not confined to the highlands: in New Britain, potential cultivars including bananas, *Canarium* and *Saccharum* appear before 6000 cal. BP (Lentfer et al., 2010). Importantly, the Holocene palynological signature from Kuk is not dissimilar to the Holocene records for Sumatra, Java and Borneo, discussed above, in being characterised by highly-disrupted vegetation through much of the Holocene (Haberle et al., 2012). Similarly disturbed Holocene vegetation is also evident elsewhere in highland New Guinea, for instance in the Owen Stanley Range (Hope, 2009).

## 7. Marine interchange of biota and ideas

Sahul and the lands around the Sunda rim seem to have been part of a long-lived sphere of marine interaction, as posited by Solheim (1984). Accumulating evidence points to the widespread dispersal of plants, animals and cultural items (Allen et al., 1989; Bulbeck, 2008; Denham, 2010, 2013; Barker et al., 2011; Hunt and Premathilake, 2012; Rabett and Piper, 2012). Modern molecular studies also suggest that domestication of bananas, taro, yams and sugarcane was highly complex, involving the hybridisation of taxa derived by human translocation from several parts of the region. These events probably occurred early in the Holocene, at multiple sites in Island Southeast Asia and Papua New Guinea (Carreel et al., 2002; Grivet et al., 2004; Lebot et al., 2004; Malapa et al., 2005; Denham 2010). This proposition also finds support in linguistic studies (Denham and Donohue, 2009).

**Table 1**

Early Holocene human activity in the lands around the Sunda Shelf: evidence from pollen diagrams. All dates calibrated and expressed in thousands of years BP.

Location	Citation	Background	Holocene ecology	Succession present/not present
Nong Thalee Son Hong, South Thailand	<a href="#">Maloney 1999; Kealhofer 2003</a>	Lowland lake	Lowland rainforest with disturbance indicators from the base of the Holocene	No succession present, intermittent burning, open areas maintained until ~7.2 ka
Lake Kumphawapi, Northeast Thailand	<a href="#">Kealhofer and Penny 1998; Penny 1999, 2001; Kealhofer 2002, Burke 2014</a>	Lowland lake	Holocene grassland and woody vegetation replacing Pleistocene savannah with regular fires. Disturbance indicators present throughout	Holocene succession of temperate and then tropical woodland taxa but woody vegetation is a minor component of vegetation. Intermittent burning through early-mid Holocene. Penny suggests intensification of burning ~7.4 ka. Succession disrupted through Holocene. Strong clearance and agriculture from 0.4 ka.
Rawa Danau, West Java	<a href="#">van der Kaars et al., 2001</a>	Lowland swamp/lake	Open grassy vegetation with much evidence for fire from 15.7 ka succeeded by Lowland forest with high proportion of disturbance indicators in Early Holocene	No succession apparent. Poorly dated and possibly discontinuous sequences.
Niah Cave, Sarawak	<a href="#">Hunt et al., 2012</a>	Karst tower on coastal plain	Lowland forest with disturbance indicators rapidly replaces Late Pleistocene open dryland forest	Not present.
Loagan Bunut, Sarawak	<a href="#">Hunt and Premathilake 2012</a>	Back estuary	Lowland forest and mangroves from ~11.2 ka: disturbance indicators and charred material frequent	Succession disrupted very early in the Holocene; intermittent disturbance thereafter.
Danau Padang, M.t Kerenici, Sumatra	<a href="#">Morley, 1982</a>	Lake in upland valley	Lower Montane and swamp forest with prominent disturbance indicators from early in Holocene. Major canopy opening after ~9.6 ka	Succession disrupted ~10.5 ka, then intermittent disturbance, diminishing ~5 ka. Charcoal intermittently present Clearance and canopy opening 1.6 ka
Tao Sipinggan, Toba Uplands, Sumatra	<a href="#">Maloney 1996</a>	Lake in Toba Uplands	Lower Montane forest with disturbance indicators from ~10.5 ka	Succession present but interrupted by peak of herbs ~10.4 ka.
ND1, Son Hong (Red River) Delta, Vietnam	<a href="#">Li et al., 2006</a>	Back estuary	Lowland forest and mangroves: succession from semi-open, through temperate to subtropical forest ~11.6–9.4 ka. Disturbance ~10.4 ka	Succession disrupted ~10–7.5 ka, charcoal present
Ranca Upas, West Java	<a href="#">Stuijts, 1993</a>	Upland lake	Lower Montane rainforest with disturbance indicators from ~10 to ~7.5 ka and from ~4 ka–recent	Succession disrupted
Danau di-Atas, Sumatra	<a href="#">Newsome and Flenley, 1988</a>	Lake in Sumatra Uplands	Lower Montane forest with disturbance from ~9.6 ka	No dryland succession apparent.
Batulicin, Kalimantan	<a href="#">Yulianto et al., 2005</a>	Coastal mangroves	Coastal mangroves from ~9.1 ka, transitioning to peat swamp. Strong representation of disturbance indicators throughout.	No succession apparent.
Pea Sim–Sim, Toba Uplands, Sumatra	<a href="#">Maloney, 1980</a>	Lake in Toba Uplands	Lower Montane and swamp forest with prominent disturbance indicators from early in Holocene. Major canopy opening after ~8.2 ka	No succession present.
Rawang Sikijang, Mt. Kerenici, Sumatra	<a href="#">Flenley and Butler, 2001</a>	Swamp in upland valley	Submontane forest with disturbance indicators from base of Holocene. Clearance with grassy patches from ~8 ka	Succession shows replacement of <i>Dacrydium</i> , <i>Eugenia</i> , then <i>Castanopsis</i> , then <i>Quercus</i> before major disruption of vegetation and development of scrub ~7.5 ka.
Pea Bullok, Toba Uplands, Sumatra	<a href="#">Maloney and McCormack, 1996; Maloney, 1996</a>	Lake in Toba Uplands	Lower Montane and swamp forest with disturbance indicators from base of Holocene. Major canopy opening after ~7.5 ka	No succession apparent. Climate dries 5 ka
Laguna de Bay, Luzon	<a href="#">Ward and Bulalacao, 1999</a>	Coastal lagoon	Coastal savannah progressively replacing dry lowland forest. Record starts ~7 ka	No succession apparent. Climate dries ~5 ka
Paoay Lake, Luzon	<a href="#">Stevenson et al., 2010</a>	Coastal lagoon	Coastal savanna with montane pine forest upslope. Record from ~6.5 ka shows disturbance indicators from base. Burning of woody biomass replaced by burning of grasses at 5 ka. Disturbance indicators become more common 3.7 ka	Back mangrove succession to freshwater disrupted by burning and possible cultivation.
Kampong Irang and Gan Kira, Niah, Sarawak	<a href="#">Hunt and Rushworth, 2005</a>			



Kelabit Highlands, Sarawak	Jones et al., 2013a,b	Back-mangrove swamps passing up into alluvial deposits Fluvial cutoffs	Mangroves burnt ~6.5 ka. Rice-type pollen and clearance indicators accompany deposition of clays in unshaded environments until very recent times Montane forest with discontinuous sequences from 6.4 ka Core starts ~10.7 ka. Wooded savannah until ~9.3 ka, then dense monsoonal forest until ~5.4 ka. Then major drying and disruption of forest with many disturbance indicators. Probable Holocene Teak forest. Sequence likely to be discontinuous before ~2 ka.	Short successions showing fire and possible sago and fruit tree arboriculture from 6.4 ka Successions interrupted by climatic change at ~9.3 and ~5.4 ka. Swiddening and controlled burning suggested to start 3.5 ka
Lakes Kara and Yeak Laom Cambodia	Maxwell 2001, 2004	Lowland lake		
Phayao, Northeast Thailand	Penny and Kelhofer, 2005	Lowland lake		Disturbance from ~2 ka. Record incomplete before this point.

Evidence of animal translocation is older, first appearing in the Pleistocene in Sahul with the movement of the cuscus *Phalanger orientalis* from New Guinea to New Ireland (Heinsohn, 2003). Further Pleistocene translocations *P. orientalis* include the Solomon Islands, Bismark Archipelago, Moluccas (Heinsohn, 2003) and Timor (Anderson and O'Connor, 2008). At around the same time other introductions occurred: *Dorcopsis muelleri*, a wallaby, to Gebe and Halmahera; *Thylogale browni*, the northern pademelon to New Britain and New Ireland and *Spiloglossus maculatus*, the common spotted cuscus, to New Ireland, Ambon, Pandar and Seram (Flannery et al., 1998; Heinsohn, 2003). Translocation continued during the Holocene, since genetic work suggests that *Sus celebensis*, the warty pig, was introduced to Flores and the Moluccas around 7000 years ago (Larson et al., 2007; Dobney et al., 2008; van den Bergh et al., 2009), an ovicaprid is reported from East Timor around the same time (Glover, 1986) and dogs seem to have spread, according to genetic studies, before 4000 years ago (Oskarsson et al., 2012). A series of later introductions are listed by Bulbeck (2008). Although much of the early evidence for animal translocation is located in Sahul, movement of animals such as dogs and ovicaprids into that region must necessarily have involved them being carried through the lands of the Sunda rim. Together, animal, plant and cultural translocation are convincing evidence for active marine interaction over very extended periods during the Late Pleistocene and Early Holocene.

## 8. The rise of 'management mentality'

Pleistocene anthropogenic biomass-burning (Haberle et al., 1991; Hope 2001; Hunt et al., 2007, 2012; Summerhayes et al., 2010) and translocation are rather significant because they imply the early existence of a 'management mentality' (Riede, 2007, 2009) of human niche construction (Kendal et al., 2011; Smith, 2011; Hunt et al., 2012) where people actively influenced and enhanced the possibilities offered by the environments in which they lived. It can be argued that detoxification of aroids and *Pangium* nuts (Barker et al., 2007), development of sophisticated hunting strategies (Rabett et al., 2006) and even management of the human dead (Harrison, 1967; Hunt and Barker, in press) in the Late Pleistocene at Niah also reflects this mentality. Such behaviours can be regarded as evidence for a mental step which could facilitate development of the activities we call farming, although, clearly, no directionality was intended by the people who did this, or is implied here.

## 9. A hypothesis of Holocene landscape management around the Sunda Shelf

It may perhaps be argued that Late Pleistocene biomass-burning based landscape-management practises may eventually have developed into the range of land management and food production strategies known in the recent past from the lands of the Sunda rim. The early appearance of translocated *Metroxylon* at Loagan Bunut (Hunt and Premathilake, 2012) implies that propagation of plants had started very early in the Holocene in the region. A minimal interpretation of the sago pollen evidence from Loagan Bunut might be a form of 'plant and leave'. Groups such as the Penan in Borneo still claim to practice 'plant and leave' strategies with sago (Kedit, 1982), although they have also adopted an 'explicit stewardship' of this resource (Brosius, 1991). Such activity usually involves repeated clearance of small areas to enable the young plants to thrive so is more than simple propagation. At Loagan Bunut, however, the evidence for abundant burned phytoliths of rice seems to imply a more complex, active and widely-distributed strategy.

Many of the 'plant and leave' taxa, which also include aroids and yams, are today essentially still wild in morphology and very durable to disease and wild animals. We hypothesise that as such they offered a 'gateway' into farming-like activities (see also Barton and Denham, 2011: 19–20). We have no evidence as to whether the Kuk model, where organised ditch and mound systems seem to have emerged over several thousand years, is germane outside New Guinea. Nevertheless, there is probably enough evidence to postulate plant propagation and landscape management in lowland Borneo and some form of landscape management by fire possibly associated with plant propagation (Jones et al., 2013b) in upland Borneo during the Early to mid-Holocene. The widespread regional patterns of disturbance (Fig. 1, Table 1) suggest that it is possible that similar practices were present more widely, although the paucity of multi-proxy work and the small numbers of analysed sites mean that the exact causes of these disturbances have not been firmly identified, although anthropogenic impact is reasonably deduced. It is likely that any subsistence systems associated with these likely landscape interventions were locally-contingent – prompted by the possibilities offered by specific environments across this vast region. Recent work has highlighted the diversity of traditional subsistence strategies available on the islands of the Sahul Shelf (e.g. Kennedy, 2012; Denham, 2010, 2013) and around the Sunda rim (Rabett, 2012: 273–276; Kedit, 1982; Brosius, 1991; Wiersum, 1997; Latinis, 2000; Salafsky, 1994; Mulyoutami et al., 2009) and it is unlikely that all of these were recent innovations.

Although much of the evidence outside New Guinea remains equivocal, the signature of Holocene forest disturbance (and thus the possibility or probability of forms of landscape intervention) is consistently found over vast areas. In particular, records from across the wider region of the Sunda rim present a very different view of the initiation of landscape management and agricultural systems than might be expected if the first clearances were by rice-using farmers from the Austronesian diaspora. They also present a very different version of events from the customary interpretations of the SW Asian/European Neolithic model, since in much of this region, farming never fully replaced foraging until recent plantation agriculture. The economic base in the islands of the Sunda rim was never completely focussed on grain crops or domesticated animals, but instead included a wide variety of economically useful species and a range of behaviours, potentially similar to the 'plant-and-leave' stewardship of wild forms on one hand, to full cultivation of domesticated forms on the other. Some of these differences are undoubtedly because of the lack of animals amenable to domestication, and thus a scarcity of domesticated animal protein, necessitating the retention of hunting areas. The relatively low long-term fertility and low productivity of tropical agroecosystems forced a pattern of shifting cultivation in many areas and did not enable populations to completely abandon wild foods. Over large areas forests became cultural artefacts (Barton et al., 2012) of secondary growth which one distinguished early scientist described as 'well-worked' since 'time immemorial' (Gibbs, 1914: 9–10), with vegetation shaped by consistent and purposeful patterns of management. Today, groups such as the Kelabit of upland Borneo grow rice and it is indeed one of the defining parts of their culture, but it still has to be supplemented as a food source by other crops and wild foods (Janowski, 2004) and is in many ways a cultural marker and status symbol rather than a subsistence crop (Barton, 2010). Managed forests, forest gardens, species-enriched fallows, and other forms of semi-cultivation/management, vegiculture and arboriculture are also widely reported (e.g. Wiersum, 1997; Sellato, 2001; Salafsky, 1994; Mulyoutami et al., 2009; Latinis, 2000; Kennedy, 2012). It is very questionable whether true domestication (morphological and behavioural change) of many of the plants involved in these systems ever occurred. In many ways this

situation parallels, but in a highly-extended way, that in 'transitional' phases at the beginning of cultivation elsewhere in eastern Asia (Crawford, 2011, 2012; Lee, 2011; Zhao, 2011).

The trajectory of the use of landscape and the modification of vegetation is, through most of the study region, unlike those reported elsewhere following the earliest Neolithic, although there may be some parallels with other areas outside Europe, for instance the postulated development of Maya forest-gardens (Ford and Nigh, 2009). Other post-Early Neolithic systems might be argued to have had relatively high agricultural productivity and the storage of agricultural products, which together provided the basis for the rapid growth of population, causing 'land-hunger' which removed uncultivated reservoirs of wild food species. In the study region, only where intensive rice agriculture was adopted, in some parts of mainland Southeast Asia, did highly stratified complex societies arise, with storage and redistribution systems, monumental buildings and highly developed material and social culture. Elsewhere around the Sunda rim, low agricultural productivity, difficulties associated with long-term storage of tubers and products from tree crops and, perhaps most particularly, the long-term persistence of adaptive strategies that had developed to successfully exploit the highly diverse and highly localised environments, propelled communities along a distinct trajectory of economic change (Rabett, 2012). What seems to have occurred in Borneo and quite possibly much more widely may be interpreted as a very protracted version of wild plant food production (Harris, 1989; Fuller et al., 2007) or cultivation without domestication (Zhao, 2011) rather than the progression from wild plant food procurement to the agricultures of domesticated species which underpinned the 'Neolithic Revolution' in Western Asia, Europe and China.

## 10. Conclusion

In this paper we have linked evidence of disrupted forest successions in Southeast Asia to a likely widespread pattern of landscape intervention during the Early Holocene. High resolution evidence from Borneo suggests that translocation and propagation of economically-useful plants was associated with these disrupted successions, and that there is a complex early to mid-Holocene prehistory of food production before the Austronesian 'Neolithic'. Although there are indications that this is representative of a wider reality, the regional record often remains enigmatic about the exact outcome of this anthropogenic activity; although the disrupted successions provide evidence that that it was occurring. Nonetheless, the palynological signature of forest disruption around the Sunda rim bears sufficient similarity to that associated with the transition to cultivation economies in New Guinea to lend weight to the validity of this interpretation. It may perhaps be argued from the evidence discussed here that the long term patterns of human intervention over extensive areas around the Sunda rim means that the rainforests of the region were, at first Western contact, not 'natural' in the sense of being unaffected by human activity. Indeed, we can echo Gibbs (1914) in regarding much of the low altitude to lower montane vegetation of the region as a long-established cultural artefact.

Economic trajectories between communities around the Sunda rim and from those within Sahul are bound together by increasing evidence for an early onset of maritime interchange between these neighbours; one that continued through the Early Holocene and arguably renders less potent some arguments supporting the Austronesian expansion. It is now apparent that, before its advent, certain behaviours which we might otherwise class as 'Neolithic' were already in existence. These included plant dispersal, management and propagation, exchange of technology, animals (and

genes), but that these are likely to have existed within a range of localised economies where subsistence innovation continued to proceed hand-in-hand with traditional hunting and gathering rather than to replace it. The Austronesian Hypothesis has been an immensely successful paradigm, which has opened up a huge area of the Earth's surface to serious archaeological investigation and has provided a vehicle for a great deal of outstanding research and scholarship, little of which would have been possible – or even contemplated – without it. While we are not advocating that the theory should be discarded, we suggest from the evidence summarised here that this sweeping narrative be reassessed and that more nuanced explanations might be considered.

Finally, seeing a dichotomy between hunter-gatherers on one hand and agriculturalists on the other is rather unhelpful as a foundation for understanding the Holocene prehistory of the mainland and islands of Southeast Asia. The Eurocentric conception of agriculture as based on cereal crops and animal domesticates is too narrow to encompass known patterns of activity, which were far too complex, nuanced and locally-contingent to be attributed neatly to simple economic categories or narratives. It may be that this perspective would be helpful in examining changing Holocene subsistence systems elsewhere.

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