Quaternary International 202 (2009) 29–40

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Plant exploitation on Sahul: From colonisation to the emergence of regional specialisation during the Holocene

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ARTICLE INFO

Article history:
Available online 18 November 2008

ABSTRACT

Archaeobotanical evidence for plant exploitation in Sahul (Australia and New Guinea) and Near Oceania (Bismarck Archipelago and Solomon Islands) is reviewed for pre-20 ka BP sites. The Sahul evidence for colonisation, settlement and plant exploitation provides an analogue for understanding the diffusion of modern humans eastwards from Africa across southeast Asia and Indo-Malaysia. The patterns of behaviour exhibited by Sahulian colonists suggest that diffusion occurred across land masses, including rapid adaptation to and occupation of diverse climo-biogeographic environments of interior locales. A model is developed to understand how generalist practices and patterns of behaviour throughout the Pleistocene became more regionally specific during the Holocene, primarily from the mid-Holocene. The model focusses on how specific, or constituent, practices were variously bundled, or occurred together, in different places and times in the past. Different forms of plant exploitation recorded in the recent past across Australia and New Guinea are shown to have emerged from compounded differences of emphasis, cumulative effects and attendant transformations through time.

1. Introduction

Adherents of the 'Out-of-Africa' hypothesis draw on various lines of archaeological, genetic and geophysical evidence to propose diverse models for the timing and routes of dispersal of modern humans, *Homo sapiens sapiens*, from Africa across Eurasia and Indo-Malaysia to Australasia (Foster and Matsumura, 2005; Macaulay et al., 2005; Mellars, 2006; Vaks et al., 2007). Coastal (Stringer, 2000; Macaulay et al., 2005) and 'adaptation to estuaries' (Bulbeck, 2007) models are currently favoured, although other models have been proposed, e.g., savanna corridors (Bird et al., 2005). The proposed routes are all highly speculative, filling a space largely devoid of data, and timelines are similarly vague. People may have diffused from Africa in a single or multiple migrations, early (c. 140–110 ka BP; Vaks et al., 2007) or late (c. 75–60 ka BP; Stringer, 2000), with rapid colonisation of Asia from c. 65 ka BP (Macaulay et al., 2005) and colonisation of Australia by c. 45 ka BP (see below). Given uncertainties of timing and routes, in part reflecting discrepancies between archaeological and genetic evidence, diffusion of people across land masses between Africa and Australia occurred over an extremely variable time period ranging from >60,000 to <15,000 years. Unfortunately timescales are essential to understanding diffusionary processes, in this case, how people lived in landscapes to produce a net expansion of occupied land through time.

Equally unfortunate is the language used to discuss this particular human diffusion. Terms such as 'migration' and 'journey' imply intentionality; a sense of directionality and purposefulness is read into the past. This was certainly not the case and detracts from an understanding of the fundamental process underlying this diffusion, namely, how people lived in the world. Net diffusion through time was simply a by-product of how people lived in landscapes. Diffusion is likely to have been incremental and non-linear, to have occurred along the coast and inland, and to have favoured certain types of environment, relative to group knowledge and technology. Over tens of millennia such processes could result in expansive colonisation across vast land masses, such as Eurasia and Australia. Certainly the emerging archaeobotanical record from Niah Cave on Borneo demonstrates that the interior rainforests of Southeast Asia were occupied in relatively sophisticated ways before 40 ka BP (Barton and Paz, 2007), were not inhibitors of human occupation, and were certainly important environments for human diffusion. This is a very different type of process to the estuarine-hopping paddlers of the rapid-southern-dispersal hypothesis (Bulbeck, 2007; after Macaulay et al., 2005), whose demographically induced wanderlust bears echoes of the assumptions and portrayals of

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doi:10.1016/j.quaint.2008.06.018

Austronesian-speaking colonists voyaging across Island Southeast Asia and the Pacific during the mid- and late Holocene (e.g., Diamond, 1988).

Furthermore, some routes and models are neither testable nor falsifiable, calling into question their epistemological status. For example, proposed coastal or estuarine-focussed diffusion occurred at times when sea levels were at least 40 m below present levels (Lambeck and Chappell, 2001); any associated sites would be deeply buried and unlikely to be found except in areas of uplifted land surfaces, e.g., Huon Peninsula (Groube et al., 1986). In the event that such finds are forthcoming, they could accord with 'any other habitation or colonisation model that did not specifically rule out use of coastal resources' (Bulbeck, 2007: p. 319). Thus new finds are unlikely to either negate or verify some 'hypotheses'. In sum, the handful of relevant sites across Eurasia and Australasia are consistent with a great range of competing scenarios for human diffusion which, although creative, foster a highly relativistic intellectual milieu and provide little evidential ground upon which to judge.

In this paper, we review the evidence for plant exploitation across Sahul and Near Oceania. Sahul is the focus here and refers to the land mass comprising Tasmania, Australia, New Guinea and other islands during periods of lower sea level. Near Oceania comprises the Bismarck Archipelago and the Solomons that were colonised during the Pleistocene. We leave aside faunal resource exploitation – whether gathered, fished, scavenged or hunted – a subject worthy of separate and lengthy consideration (see Cosgrove and Allen, 2001). Our argument clusters around three themes. First, we argue that the nature of human behaviour following the colonisation of Sahul provides an analogue to understand how people dispersed across southern Eurasia and Indo-Malaysia. Patterns of behaviour exhibited by Sahulian colonists provide a window, albeit highly partial, to understand preceding patterns of behaviour that were forged over millennia – potentially tens of millennia – across Indo-Malaysia and regions to the west. Second, we draw on highly fragmentary data from Australia, New Guinea and Near Oceania to sketch how plant exploitation changed from the Pleistocene to the Holocene. We evaluate records to conclude that regional variations in plant exploitation practices were limited during the Pleistocene, and show how interpretative frameworks derived from the recent past have distorted interpretations of the more distant past in Australia and New Guinea. Third, we develop a heuristic framework to illustrate the bundling and transformation of plant exploitation practices in tropical regions of northern Australia and New Guinea during the Holocene. Recent differences in forms of plant exploitation in Australia and New Guinea originated during the Holocene largely through the accumulation of different emphases rather than being borne of a fundamentally different way of living in the world. In conclusion, we offer some directions for future research designed to complement each of the three themes; these contribute to the much bigger project of seeking to understand how Sahul's inhabitants have adapted, and continue to adapt, to a vast and environmentally diverse continent.

2. Colonisation of Sahul: in brief

A conservative interpretation of the archaeological evidence suggests that people colonised Sahul by 45–42 ka BP (O'Connell and Allen, 2004, 2007), whereas more speculative interpretations push the date to as early as 60–55 ka BP (Roberts et al., 1994; Turney et al., 2001; Bowler et al., 2003). Resolution of this debate is unlikely in the short-term given dating imprecision and limitations, and uncertainties of archaeological association and site formation. Consequently, a conservative estimate of 45 ka BP for colonisation of Sahul is adopted here.

Several routes have been proposed for human dispersal to and across Sahul; these are as speculative and as devoid of data as those for regions to the west. Proposed southern and northern routes (from Birdsell, 1977 to Bulbeck, 2007) largely reflect chains of islands on maps (cf. Irwin, 1992) and parsimony: people are considered likely to have undertaken shorter rather than longer maritime crossings. Exploration of coastal Sahul must have entailed maritime technology and was probably accompanied by overland exploration. Maritime technology was certainly available and retained to colonise the Bismarck Archipelago. Indeed, maritime colonisation was retained during the Pleistocene and Holocene to enable: colonisation of Manus (Fredericksen et al., 1993) and the Solomons (Wickler, 2001), inter-island trade in Near Oceania (Summerhayes and Allen, 1993; Summerhayes, 2003), and spheres of mid-Holocene interaction between New Guinea and the Bismarck Archipelago (Araho et al., 2002; Swadling and Hide, 2005).

Archaeological evidence indicates that people rapidly colonised spatially and ecologically disparate regions across Sahul. Early, or pre-40 ka BP sites have been found around the periphery of the continent; most are coastal or hinterland locations, only one is inland and none occur in the arid interior (Fig. 1). Many maps of early sites and pre-LGM colonisation display the current coastline and that of the lowest LGM sea level when sea levels were about 120 m down from the present shore (e.g., O'Connell and Allen, 2004: Fig. 1). These depictions are misleading since sea levels during the period of putative colonisation were probably only 50–75 m down from current sea levels (see Fig. 1; after SahulTime, 2007).

Although exhibiting a coastal bias, people rapidly colonised a range of climo-biological zones:

- wet tropical rainforests of eastern New Guinea (Huon – Groube et al., 1986) and New Ireland (Buang-Merabak – Leavesley et al., 2002),
- savanna/grasslands of subtropical northwestern Australia (Carpenter's Gap – Fifield et al., 2001; Riwi – Balme, 2000),
- monsoonal tropical forests of northwestern Australia (Nauwalabila – Roberts et al., 1994; Malakanunja II– Roberts et al., 1990),
- temperate southwestern Australia (Devils Lair – Turney et al., 2001), and,
- semi-arid regions of interior, southeastern Australia (Lake Mungo – Bowler et al., 2003).

If, based on inter-generational experience in Indo-Malaysia, colonists were restrictively adapted to tropical climates or focussed upon coastal environments, as some early sites and models suggest, why were people living around Lake Mungo in the semi-arid southeast so early? Despite sampling bias and uncertainties of record, we would anticipate the earliest sites to be restricted to the tropics and coasts, with some temporal persistence of this restricted distribution prior to subsequent broader dispersal. Certainly over the next ten millennia, people had adapted to every type of environment in Australia and New Guinea, with archaeological evidence for more widespread occupation including the rainforests of highland New Guinea (Fairbairn et al., 2006) and lowland New Britain (Pavlides, 2004), tropical northwestern Queensland (David et al., 1997), the arid interior of Australia (Smith et al., 2001), and cool temperate southern Tasmania (Cosgrove, 1995).

Although archaeological sites provide some chronological information on the presence of people, this information, like the paucity of information on so many aspects of the human past during the Pleistocene, should not constrain our thinking of human dispersal and behaviour during the first 15,000 years of occupation. The dispersal of people to tropical, temperate and semi-arid

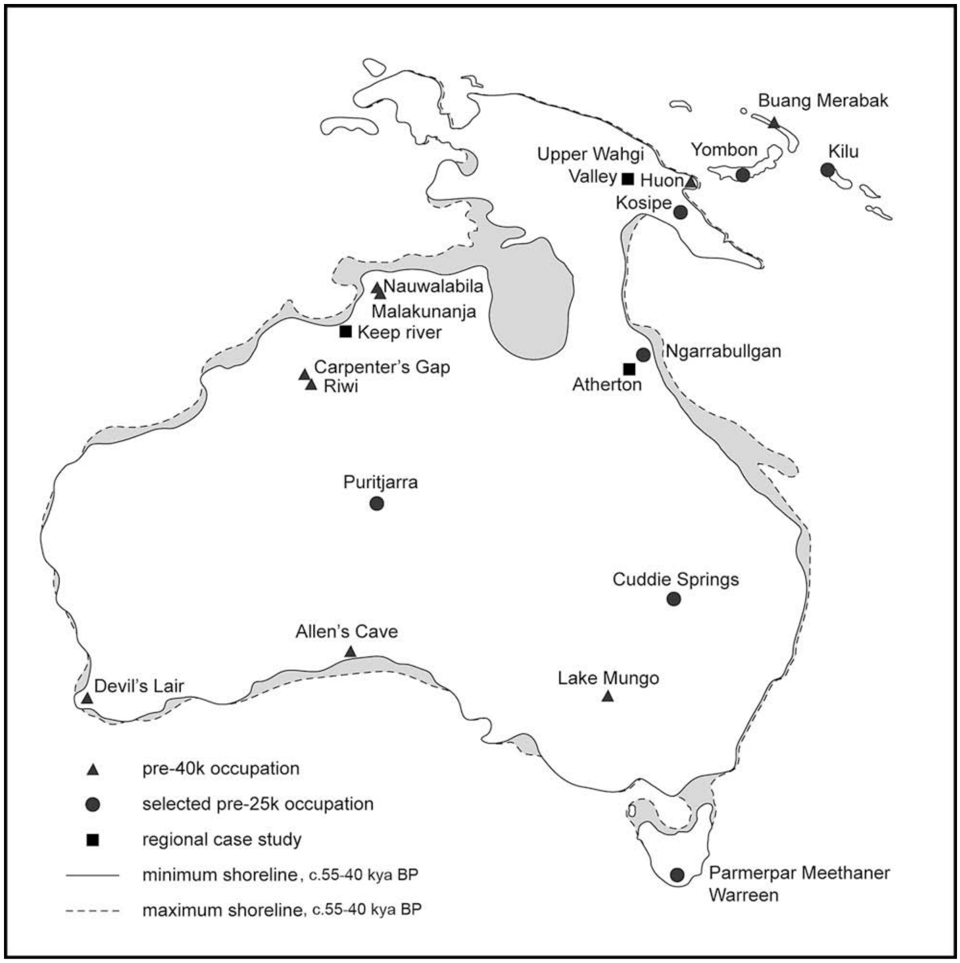


Fig. 1. Map of Sahul and Near Oceania depicting sites and regions discussed in the text. Note the shoreline depicts the maximum and minimum shorelines present between 55 and 40 ka BP (based on SahulTime, 2007), which represents the most likely period of human colonisation.

environments soon after colonisation, with evidence for the continued occupation of these regions (see O'Connell and Allen, 2007), as well as intermittent occupation of the arid interior (Smith et al., 2001), indicates that colonists were able to rapidly adapt to new environments. This adaptability would seem to suggest that people had not been environmental/niche specialists – whether coastal, estuarine, rainforest or savanna – during the colonisation of Indo-Malaysia; rather, they had been generalists, diffused across land masses, and almost certainly inhabited a range of different coastal and inland environments.

Prior to arriving in Sahul, people had dispersed across the tropical regions of mainland and island Southeast Asia for millennia. Consequently it can be assumed that people were familiar with coastal and tropical rain forest environments, as well as potentially tropical savannas (after Bird et al., 2005). They would have had limited experience of arid, semi-arid and temperate environments. However, this lack of familiarity did not constrain their exploration and settlement of these environments once they dispersed to Sahul. What enabled this rapid adaptation to the unfamiliar environments of Sahul?

3. Common ground: plant exploitation during the Pleistocene

In a recent review, O'Connell and Allen characterised any pre-LGM occupation of Australia and New Guinea as representing "short-term occupation by small, wide-ranging groups exploiting a relatively narrow subset of potential foraging opportunities" (2007: p. 401). Although people may have exploited only a relatively limited range of resources in any locale, the Sahul evidence suggests people exhibited generalist behaviour and adaptive flexibility in the ways they exploited resources in diverse environments. These flexible behavioural patterns were built around some basic practices and technologies: fire and stone tools for habitat modification and flexible, broad-spectrum plant exploitation, as well as faunal exploitation (not discussed here).

The aridification of Australia has occurred throughout the Pleistocene, with less clear-cut patterns for tropical New Guinea (Hope and Haberle, 2005: pp. 542–544). The role of human colonisation in exacerbating burning and vegetation change in Sahul is regionally specific and seems to be clearer where environments were already sensitised to disturbance by climatic changes (Kershaw et al., 2006). Several long marine and terrestrial palaeoecological and fire records extend from prior to colonisation towards the present, enabling interpretation of climatic cyclicity, long-term climatic trends (such as increasing aridity during the Pleistocene) and human influences (see Kershaw et al., 2006). Certainly climates were in flux at around the time of human colonisation, including the potential attenuation of the northwestern monsoon accompanying decreasing January insolation and increased ENSO 'power' (Tudhope et al., 2001; Kershaw et al., 2006; Kershaw, 2007). These climatic changes complicate the interpretation of land management practices, especially for inferential arguments of human-induced burning, vegetation change and megafaunal extinction (e.g., Miller et al., 1999, 2005); the contribution of climate change to these transformations may well have been greater than previously supposed.

3.1. Habitat modification and plant exploitation

The inhabitants of Sahul plausibly used fire to modify their landscape since colonisation (Turney et al., 2001; Kershaw et al., 2006). Fire was used for hunting and managing game (Bowman et al., 2001) and to promote growth, production and densities of favoured plants (Jones, 1969; Gott, 2005; cf. Vigilante and Bowman, 2004). Groups in different parts of the continent, and at different times in the past, variably used fire to promote game and plants for human consumption. As well as fire, stone tools, such as 'waisted' and tanged artefacts, could have contributed to vegetation change through understorey clearance and ring-barking of larger trees (Groube, 1989). Thus, colonists had at their disposal technologies to enable extensive, persistent and cumulative changes to their environments. However, these technologies were differentially applied between and within regions.

Only at a few sites was anthropic burning coeval with colonisation (Turney et al., 2001), whereas there is considerable chronological and regional variability, and inconsistent directionality, for most terrestrial and marine records around Australia and New Guinea (Hope and Golson, 1995; Kershaw et al., 2006). For example, the earliest anthropic burning in New Guinea pre-dates c. 36 ka BP at Kosipe Swamp (Fairbairn et al., 2006), with regionally specific and non-cumulative signals from 20 ka BP to the early Holocene (see review in Denham, 2004). Only at two sites in the highlands – Kelela Swamp, Baliem valley (Haberle et al., 1991) and Kuk Swamp, Upper Wahgi valley (Denham et al., 2004) – do relatively continuous records exhibit cumulative and persistent anthropic transformations from the early Holocene that culminated in the formation of 'agricultural landscapes' (after Haberle, 2003). By contrast, other sites in the highlands show no disturbance until c. 300 years ago (Hope et al., 1988).

Against this backdrop of variable habitat modification, there is limited archaeobotanical evidence of plant use in Australia, New Guinea and Near Oceania before 20 ka BP (see Figs. 2 and 3):

- At Carpenter's Gap, northwestern Australia, botanical remains spanning the last 40,000 years (McConnell and O'Connor, 1997; McConnell, 1998) include *Terminalia* spp., *Vitex glabrata*, *Ampelocissus acetosa*, *Celtis* sp. (potentially Holocene only), Chenopodiaceae, Amaranthaceaea, Cyperaceae, *Panicum* sp., *Aristida* sp., *Plectrachne* sp. and *Adansonia gregorii*. Ethnographic data, relative abundance and taphonomic considerations (e.g., burning) suggest many of these taxa were consumed as food or otherwise utilised, although there is no direct proof and the evidence is somewhat equivocal for several species.
- At Ngarrabullgan, northwest Queensland, unidentified starch residues from stone tools represent plant use at c. 37 ka BP (Fullagar and David, 1997);
- At Cuddie Springs, in semi-arid New South Wales, grinding stones date to c. 30 ka BP and one from a c. 27 ka BP context contained starch and phytolith residues indicating the processing of grasses, potentially lily bulbs and ferns, including cf. nardoo (*Marsilea drummondii*) (Fullagar et al., 2008);
- At Lake Mungo, in semi-arid southeastern Australia, starch tentatively identified as *Ipomoea polpha* was extracted from a stone tool dated to at least 30 ka BP (Loy, 1990);
- At Kosipe Mission Site, New Guinea, macrobotanical remains indicate exploitation of *Pandanus* sp. at an open site before 30 ka BP (White et al., 1970; Fairbairn et al., 2006); and,
- At Kilu Cave, Buka, Solomon Islands, starch residues extracted from stone tools indicate exploitation of aroids, including probable taro (*Colocasia esculenta*) and *Alocasia* sp. at 28 ka BP (Loy et al., 1992; Loy, 1994).

The lack of data reflects a combination of factors: preservation and the limited systematic application of macro- and microbotanical techniques.

These chronologically and spatially disparate records preclude the identification of trends or patterns. They suggest persistence in the use of some plants for tens of millennia to the present, e.g., *Pandanus*, taro, *I. polpha* and nardoo, but generally represent adventitious exploitation of available flora, including trees, seed-producing grasses and carbohydrate-rich tuberous plants. The range of plants identified probably reflects the range of specimens in macrobotanical and microbotanical (starch and phytolith) reference collections, with an emphasis on certain types of food plants, more than anything fundamental about the range and types of plant exploited.

In sum, the pre-30 ka BP-year-old evidence for plant exploitation in Australia, New Guinea and Near Oceania is extremely sparse, with little added for the next ten millennia despite over 70 sites pre-dating 20 ka BP (O'Connell and Allen, 2007: p. 398). However, taken together with additional evidence from 20 ka BP to the end of the Pleistocene, several key technologies and practices emerged. These include:

- Grinding of grasses, ferns and Liliaceae in semi-arid eastern Australia;
- Processing of toxic plants from the Terminal Pleistocene/early Holocene (Smith, 1982; Fullagar et al., 2008);
- Arboreal exploitation from 30 ka BP in highland New Guinea, from c. 20 ka BP in Island Melanesia, and possibly 40 ka from Carpenter's Gap, Australia (*Terminalia* spp., *V. glabrata*, and *Celtis philippensis*).
- Exploitation of tubers and corms, comprising taro and *Alocasia* sp. from 28 ka BP at Kilu, Solomons (Loy et al., 1992), *Cyrtosperma* from 14 ka BP and a yam (*Dioscorea* sp.) from c. 10 ka BP at Balof 2, New Ireland (Barton and White, 1993), and taro and a yam exploited at Kuk Swamp, highland New Guinea from 10 ka BP (Fullagar et al., 2006).
- Transplanting, inferred from the Terminal Pleistocene for 'domesticated' *Canarium* sp. in Island Melanesia (Yen, 1996) and from the early Holocene for some food plants putatively introduced to the highlands (Hope and Golson, 1995; cf. Denham et al., 2004).

Given the patchiness of the archaeobotanical techniques applied to sites of Pleistocene antiquity, both macrofossil and microfossil, we need to read beyond the data. The data should not be read literally or constrain our thinking; simultaneously we need to be critically aware of the contexts within which the evidence is interpreted. Early utilisation of a particular wild plant species available within a particular habitat should not be considered 'a regional specialisation' simply because it might later become a distinct focus of more specialised gathering, processing or production. Although the data seem to suggest some regional specialisation deep into the Pleistocene, most specialisation emerged at the beginning of the Holocene. Even an apparently sophisticated processing technology like grinding was probably an element of very generalist exploitation (i.e., applied to a wide range of plants) and may have been even more widespread in the Pleistocene than the limited evidence currently suggests (Gorecki et al., 1997). The Pleistocene data that do exist seem to represent the adventitious application and innovation of broad-spectrum plant exploitation technologies and practices to resources – including trees, seed-bearing grasses and carbohydrate-rich roots – in different regions.

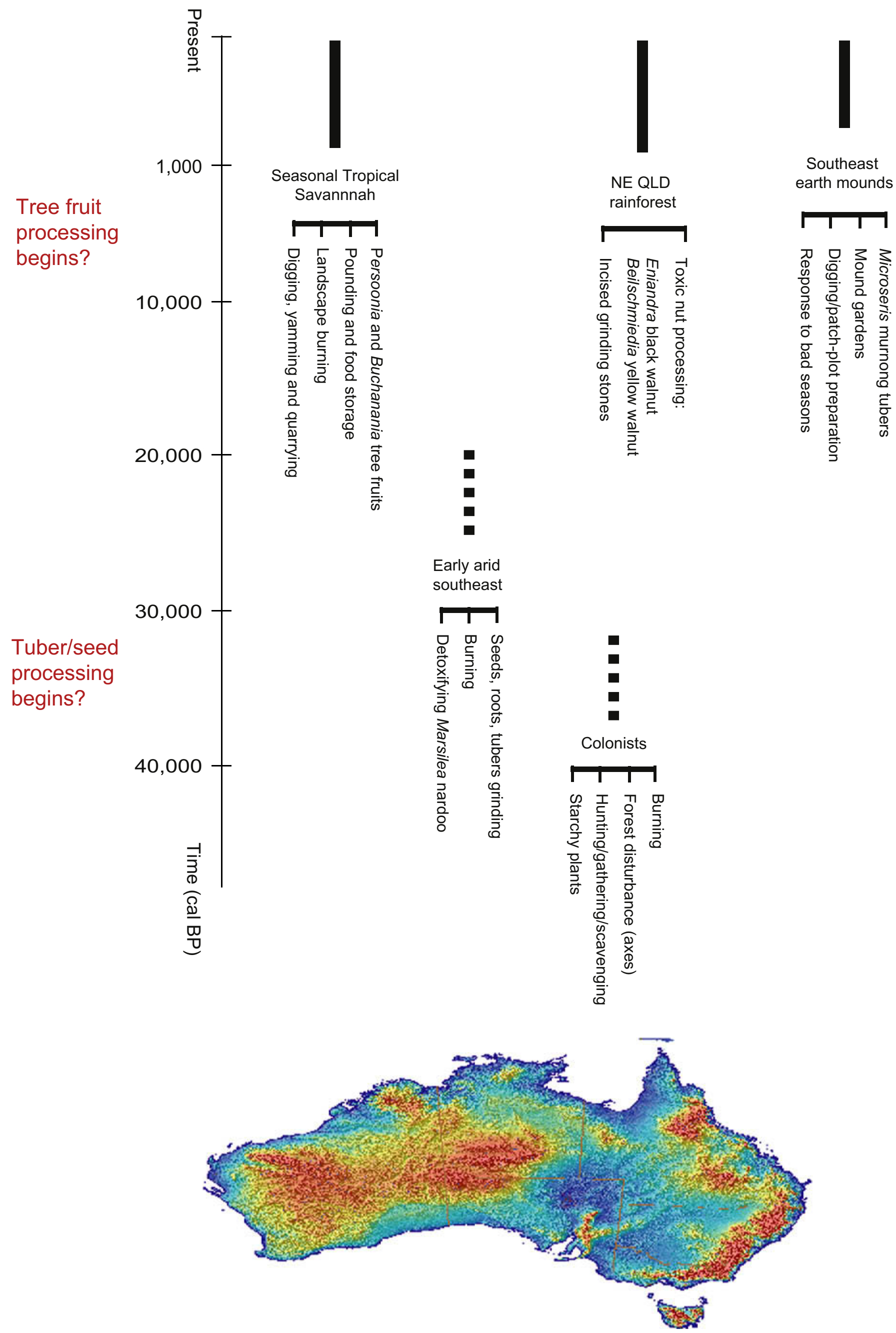


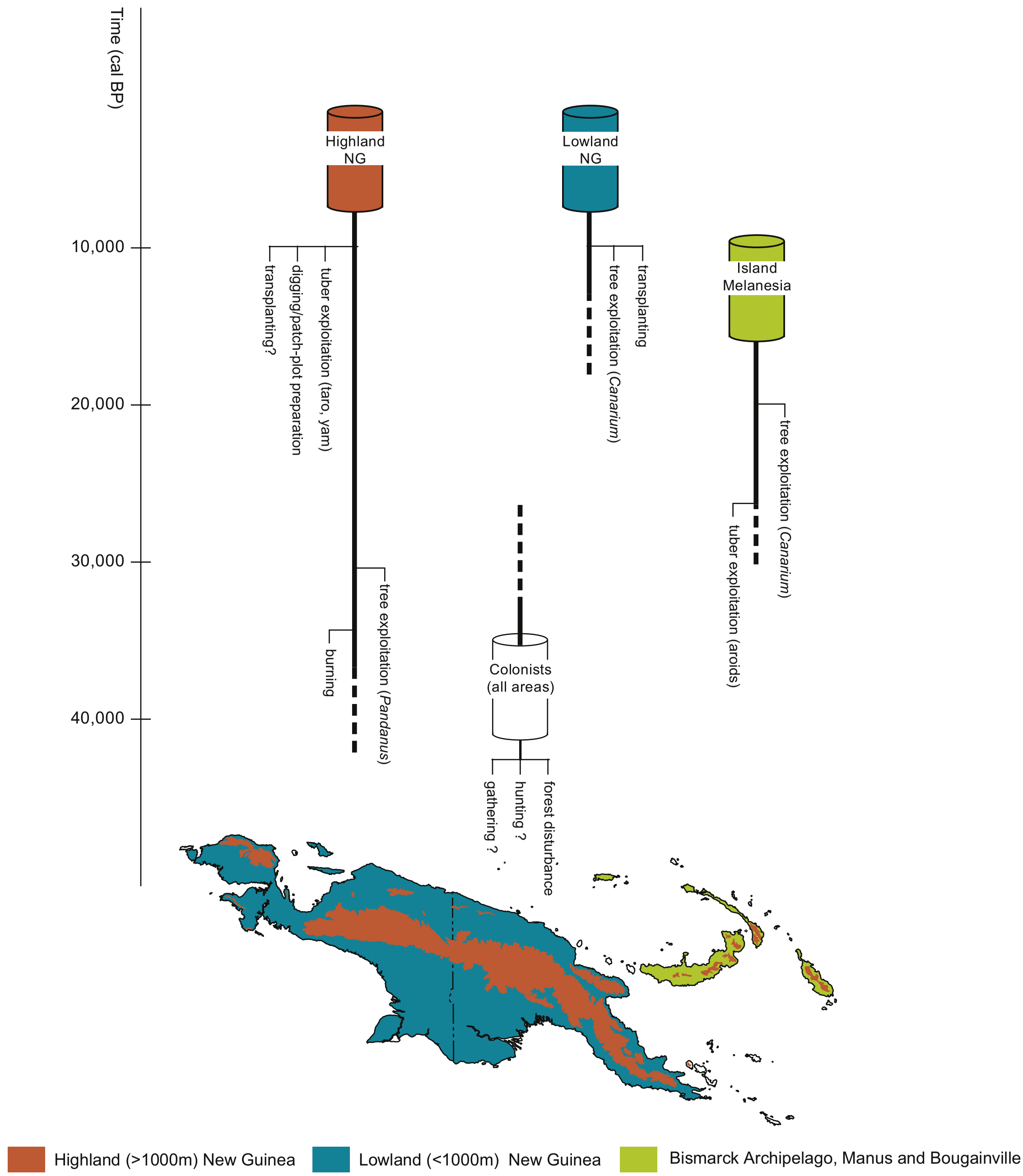
Fig. 2. Schematic and selective representation of bundling and transformation of plant exploitation in Australia from colonisation to the late Holocene (see text for discussion, except southeastern earth mounds after Gott, 1983 and Balme and Beck, 1996).

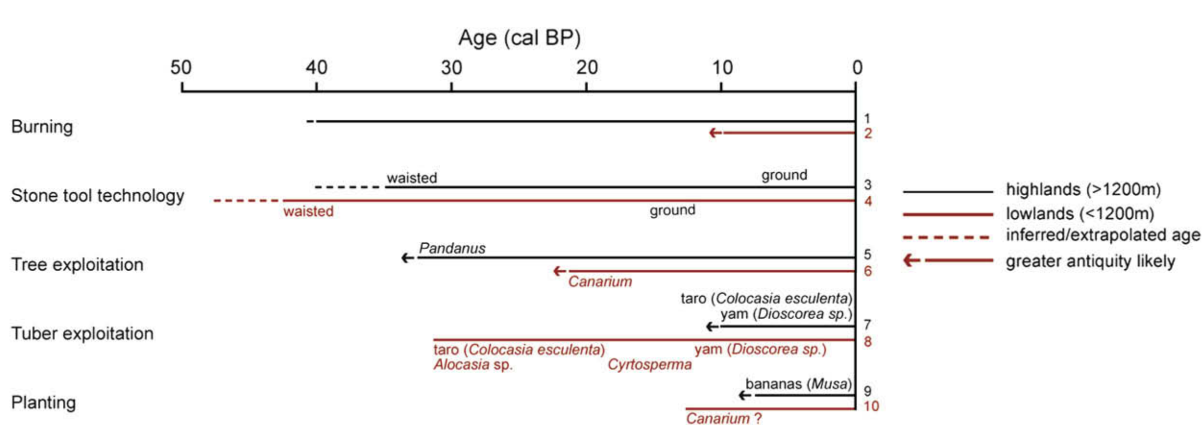
3.2. Spectres of the Holocene

Palaeoecological, archaeological and archaeobotanical evidence have been woven into very different kinds of historical narrative depending upon the region in which they occur. These historical narratives are defined less by the nature of the evidence and more by the contexts of interpretation, which are largely structured by the distributions and forms of plant exploitation during the Holocene. Effectively each type of evidence has been read teleologically, in terms of a trajectory towards relatively stereotypical portrayals of the ethnographic and historical past.

Fire and palaeoecological records of habitat modification in the highlands of New Guinea are read in terms of landscape modification for plant exploitation, which through time developed into forms of extensive and intensive agriculture. Traces of essentially Holocene practices are elicited from Pleistocene forest disturbance. Although temporal transformations of human activities in particular landscapes have been important in some regions of highland New Guinea (Denham and Barton, 2006; Denham and Haberle, 2008), similar histories are not applicable to many highland valleys, to lowland New Guinea or Island Melanesia. Certainly, records of fire and anthropic vegetation change in Australia are never interpreted in terms of trajectories towards agriculture, rather they follow ethnographic analogues in restricting consideration to hunting and resource intensification in the landscape.

Stone tools, such as waisted blades, have been cited as means of habitat modification from first colonisation in Sahul (Groube, 1989).


Time (cal BP)
10,000
20,000
30,000
40,000
Highland NG
Lowland NG
Island Melanesia
Colonists (all areas)
tuber exploitation (taro, yam)
digging/patch-plot preparation
transplanting?
burning
tree exploitation (Pandanus)
transplanting
tree exploitation (Canarium)
tree exploitation (Canarium)
tuber exploitation (aroids)
forest disturbance
hunting ?
gathering ?
Highland (>1000m) New Guinea
Lowland (<1000m) New Guinea
Bismarck Archipelago, Manus and Bougainville


Age (cal BP)
50
40
30
20
10
0
Burning
Stone tool technology
Tree exploitation
Tuber exploitation
Planting
waisted
ground
waisted
ground
Pandanus
Canarium
taro (Colocasia esculenta)
yam (Dioscorea sp.)
taro (Colocasia esculenta)
Alocasia sp.
Cyrtosperma
yam (Dioscorea sp.)
bananas (Musa)
Canarium ?
highlands (>1200m)
lowlands (<1200m)
inferred/extrapolated age
greater antiquity likely

In New Guinea, these tool types and associated activities are considered to somehow presage the development of agriculture, whereas in Australia they are not. Similarly, archaeobotanical remains of fruits and nuts are differentially interpreted depending upon where they are found. In New Guinea, archaeobotanical evidence of arboreal exploitation is woven into debates about domestication and arboriculture (Swadling et al., 1991), even though the finds may represent wild-types and claims of 'domesticated' forms (Haberle, 1995; Yen, 1996) are uncertain. In Australia, although similar types of assemblage are found, these are mostly woven into narratives regarding the antiquity, intensity and transformation of foraging practices in response to climatic, demographic or social stimuli (e.g., Lourandos, 1997; Cosgrove et al., 2007). A rare exception is Spriggs' (1993) proposition that ethnographic yamming in northern Australia might result from the transformation of a prior agricultural system (see also discussion in Lourandos, 1997: pp. 32–79).

Why are similarly patchy lines of evidence from Australia and New Guinea, which were conjoined for the time periods under discussion here, so readily interpreted in such different terms? Why are interpretations of the distant past so readily interpreted with respect to the recent past? Are ethnographic records relevant to understanding practices occurring 40 or 10 ka BP?

Multiple lines of evidence suggest these differences are artificial. Layers of meaning have been repeatedly added to the Pleistocene record of New Guinea and Near Oceania to create difference with respect to the Australian record. Effectively, the driver for these narrative distinctions is the desire to elicit trajectories for the emergence of agriculture and arboriculture in the New Guinea region (e.g., Spriggs, 1993). For example,

> The Kosipe data [dated to c. 30 ka BP] confirm the potential importance of *Pandanus* as an early food resource, extend greatly direct evidence for the antiquity of its use … and suggest that some of New Guinea's distinctive highland agricultural practices derived from the early millennia of human colonisation (Fairbairn et al., 2006: p. 379).

In each case, however, there is nothing intrinsic to the evidence that warrants these added layers of meaning; rather the various lines of evidence for the Pleistocene represent regional variations of a general suite of technologies, practices and predispositions. If we are constrained by the lens of the present in evaluating plant exploitation in the past, we follow the wrong path and look for differences of 'kind' rather than differences of 'emphasis'.

There was certainly regional variability in the *emphases* and *effects* of human activities through time and across space, which in part reflect climatic, biological and geophysical factors (contexts and resources) and in part reflect cultural differences (preferences and technologies). This assertion is justifiable because the available evidence in each region can be explained by the same behavioural patterns applied in different contexts: habitat modification (fire and vegetation clearance) to increase favoured resources; broad-spectrum plant exploitation (i.e., non-specific, although perhaps ranked, exploitation of available plant types in any given locale and the development of exploitative implements); and hunting and faunal gathering (not discussed here). Only during the Holocene does variability become marked and produce regional specialisation in plant exploitation across Australia, New Guinea and Near Oceania due to accumulating technological, botanical and environmental emphases and corresponding effects.

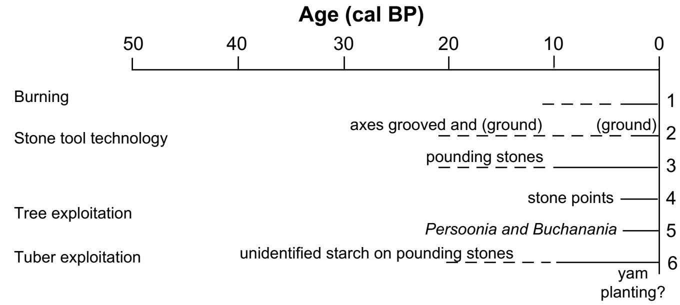


Fig. 4. Chronology of plant exploitation practices for the Keep River region, northwestern Australia. Notes: [1]Atchison et al. (2005); Head et al. (1992); [2]Dortch (1977a,b); [3]Fullagar et al. (1996); [4]Akerman et al. (2002); Fullagar et al. (1996); Ward et al. (2005, 2006); [5]Atchison et al. (2005); [6]Atchison and Fullagar (1998); Head et al. (2002).

4. Regionalisation of plant exploitation during the Holocene

A heuristic model is proposed to show how distinctive regional variations in plant exploitation emerged during the Holocene and resulted from accumulated emphases and effects inherited from the Pleistocene. Essentially, the key to understanding the emergence of variation is conceptualising how common sets of technologies and practices were bundled in given locales and then how these transformed through time, either through innovation or adoption. Bundling refers to how different practices co-occur in social, spatial and historical contexts; it invokes a contingent collection without permanence or necessary relationship. As well as integrating multiple lines of archaeological, palaeoecological and environmental evidence, this approach indicates the importance of place and historical inheritance to understanding transformations and the emergence of regional variability.

Three regions of tropical Sahul are considered: the seasonal tropical savanna of the Keep River region, Northern Territory; the rainforests of northeastern Queensland; and the Upper Wahgi valley in the highlands of New Guinea. Each region has been subject to detailed multi-disciplinary investigation, albeit not always well-integrated. For each region, some basic chronologies of practice yield distinctive signatures of habitat modification and plant exploitation through time. Only during the Holocene does multi-disciplinary evidence allow us to bundle these practices to create distinctive lifeways and forms of plant exploitation in each region.

4.1. Keep River, northwestern Australia

In the seasonal savanna, a distinctive lifeway is first visible during the last three and a half thousand years and persisted until contact with Europeans (Head et al., 2002; Atchison et al., 2005; Fig. 4). Although several technologies and associated practices extend back to the early Holocene or earlier, these are consistent with generalist behaviour, while fruit-seed processing by pounding, mainly of *Persoonia falcata* and *Buchanania obovata*, with likely storage of processed products became characteristic from 3500 years ago (Atchison et al., 2005). Atchison et al. (2005: p. 179) draw on ethnographic accounts to suggest:

Fig. 3. Plant exploitation in New Guinea and Island Melanesia from colonisation to the early Holocene. Upper: schematic diagram of bundling and transformation for highland and lowland New Guinea and Island Melanesia. Lower: chronology of key practices contrasting highlands and lowlands across New Guinea and Near Oceania. Notes: [1,5]Fairbairn et al. (2006); [2]Hope et al. (1988); [3]White et al. (1970); Christensen (1975); [4]Groube et al. (1986); [6]after Fredericksen et al. (1993); [7]Fullagar et al. (2006); [8]Loy et al. (1992); Barton and White (1993); [9]Denham et al. (2003); [10]Yen (1996).

... although short-lived, the wet season fruits provide abundant foods highly valued by both adults and children for their taste and ease of access. We can envisage large-scale processing of the fruits by groups of women to facilitate longer term storage.

Traditional landscape burning and exploitation probably encouraged localised distribution of particular species close to camping places near sandstone escarpments. Fruit-seed exploitation was accompanied by landscape burning that indirectly encouraged yields in some species (cf. Vigilante and Bowman, 2004) and a gathering of a broad array of other food plants. For example, two species of yam – *Dioscorea bulbifera* (round yam) and *Dioscorea transversa* (long yam) – were exploited for food in this region, and both are still valued today (Head et al., 2002). Yam digging, reburial/planting of tuber tops, and stone quarrying were symbiotic activities, namely, digging for yams involved excavation and stockpiling of larger previously flaked stone and other unworked blocks potentially useful for flaking. The earliest history of fruit-seed processing coincides locally with the earliest retouched stone points, some of which were used as projectile tips for hunting or fighting.

A range of multi-disciplinary evidence allows a window into the world of the people inhabiting the Keep River region. Although we focus here on plants, there are other important non-human components to this bundle, especially seasonality because it is crucial for the interaction of fruit production, fire and people. Indeed, the highly seasonal production of fruits motivated processing for storage and attendant social practices from 3500 years ago.

4.2. Tropical rainforests, northeastern Australia

A complex bundle of constituent practices in the northeast tropical rainforests can be inferred from detailed archaeological investigations and cautious integration with local climatic and palaeoecological records (Fig. 5; following Cosgrove et al., 2007). Although people were burning these rainforests from initial colonisation of the continent and are implicated in the associated transformation to sclerophyll vegetation (Turney et al., 2001), occupation by Aboriginal groups prior to 2000 years ago was apparently very low. From 2000 years ago, there is a dramatic increase in evidence of nut processing, particularly of the toxic nuts *Eniandra palmerstonii* (black walnut), *Beilschmiedia bancrofti* (yellow walnut) and *Pouteria* spp. (boxwood). Use of incised grinding stones for processing nuts is indicated by usewear and starch grains consistent with *B. bancrofti* (yellow walnut) and *Castanospermum australe* (black bean).

Cosgrove et al. (2007) propose that vegetation changes and climatic instability, associated with the onset of ENSO events c. 5000 years ago (see Turney and Hobbs, 2006), were catalysts of a human response, which involved a shift to more predictable food resources, specifically a high cost/high return food like nuts. An increase in charcoal and more open canopy species after 5000 years ago suggests an increase in rainforest disturbance, partly attributable to people, from this time. Patch creation and maintenance within the rainforest may have enhanced access to, or distribution and density of, fruit trees. Other specialised stone tools such as *ooyurka* are likely to be associated with rainforest occupation and subsistence during the mid-Holocene.

Certainly ground stone surfaces and tool edges appear to be important elements of rainforest culture from the mid-Holocene onwards, e.g., the 1913 Möberg collection includes a variety of grinding stones and axe blades (see Ferrier, 2006). Furthermore, a small (8.9 g) basalt flake with a bifacially ground edge at Jiyer Cave is estimated (from an age-depth curve) to be c. 4000-years-old (Nicky Horsfall personal communication 2007). From the same site, four metamorphic flakes (16.9–6.0 g) with smooth ground surfaces are estimated to between 4000 and 4500-years-old respectively (Horsfall, 1987, 1996, personal communication 2007). Two other metamorphic flakes are less than 200-years-old. Additionally, ground edge axes are found in undated surface occurrences, and one edge-ground axe in archaeological context dated to c. 1000 years ago at Urumbal Pocket (Richard Cosgrove, personal communication 2007).

Recent Aboriginal technologies for processing black bean (*C. australe*) include removal of seeds from pods, boiling for 6–12 h (or roasting in the ground for about 12 h) and grating with a snail shell (or a metal grater). Seeds secured in dilly bags were also leached in running water for 3–5 days and then eaten raw (Pedley, 1993: pp. 63–74). The successful and intensive exploitation of northeastern Queensland rainforest resources in the last few thousand years, and witnessed ethnographically, is in marked contrast to the apparent abandonment of Tasmanian rainforests (Cosgrove, 1996).

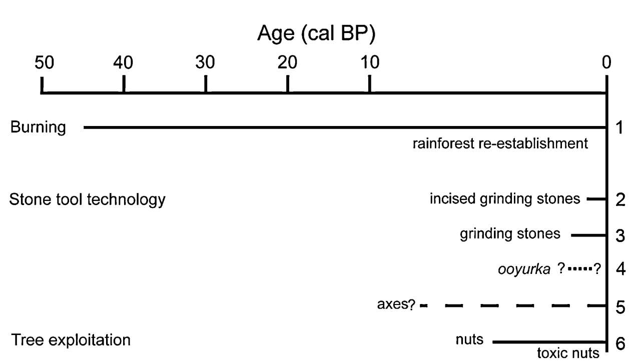


Fig. 5. Chronology of plant exploitation practices in the Atherton region, northeastern Australia. Notes: [1]Kershaw (1986); Kershaw et al. (2002); [2,3,6]Cosgrove et al. (2007); [4]Cosgrove (1984); [5]Horsfall (1987); Richard Cosgrove and Nicky Horsfall personal communication 2007.

4.3. Upper Wahgi valley

Multi-disciplinary investigations in the Upper Wahgi valley of Papua New Guinea enable the bundling of constitutive practices into discrete forms of plant exploitation during the early, mid- and late Holocene (Fig. 6; Denham and Haberle, 2008). Generalist practices inherited from the Pleistocene give rise to more specialised forms, including planting and mound construction, in the early and mid-Holocene. These newly arranged bundles represent the emergence of agriculture in the highlands from pre-existing forms of broad-spectrum plant exploitation (Denham and Barton, 2006), with subsequent transformations in diet breadth, reliance on starchy staples – principally bananas (*Musa* spp.), taro (*C. esculenta*) and potentially yams (*Dioscorea* spp.) (Fullagar et al., 2006) – types of cultivation, mobility and settlement through time (Denham and Haberle, 2008). Some practices are analogous to those of greater antiquity; for example, gap or patch maintenance, patch creation and plot preparation are functionally equivalent practices in different forms of plant exploitation that mimic and elaborate the adventitious exploitation of forest gaps.

Each form of plant exploitation and associated transformations can be heuristically charted through time (Fig. 6). The charting of continuities and transformations illustrates the potential ways in which cultivation practices arose from preceding forms of plant exploitation, as well as how cultivation practices changed through time. Importantly, one form of plant exploitation did not replace another, rather different bundling configurations and compositions broadened the repertoire through time. Thus, foraging, swidden cultivation and intensive cultivation can be envisaged to have occurred simultaneously and were practiced by the same groups, but with varying spatialities and temporalities, in the Upper Wahgi valley by c. 6500–7000 years ago.

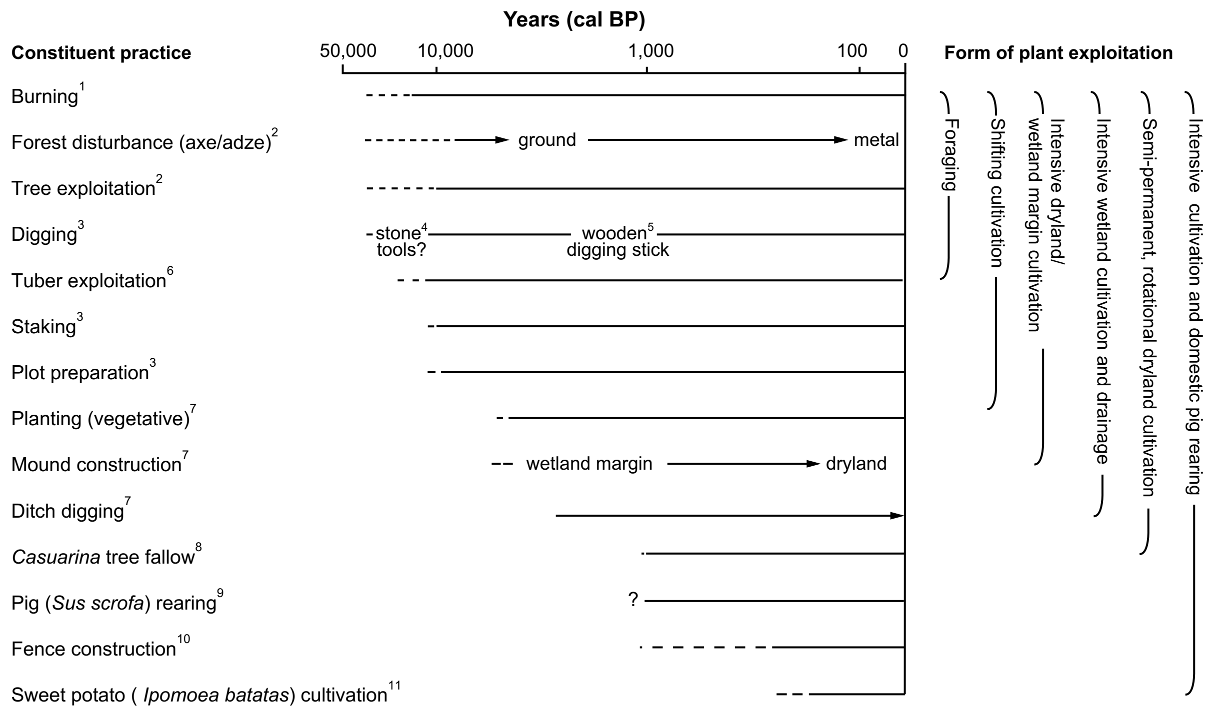


Fig. 6. Chronology of constituent practices and forms of plant exploitation in the Upper Wahgi Valley, Papua New Guinea (amended version of Denham and Haberle, 2008: Fig. 9). Notes: [1]Denham et al. (2004); [2]Christensen (1975); [3]Denham (2005); [4]Bulmer (2005); [5]Golson et al. (1967); [6]Fullagar et al. (2006); [7]Denham et al. (2003); [8]Haberle (1998); [9]Conservative estimate of introduction to the highlands; [10]Golson (1977); [11]Golson (1982).

4.4. Differences of emphasis or differences of kind?

During the Pleistocene, and potentially until approximately 4000 years ago across much of Sahul, multi-disciplinary records, although variable, largely represent similar types of practices and technologies. Differences largely reflect the socio-spatially specific ways in which common practices were bundled and the cumulative effects of these differences of emphasis through time, whether in terms of the intensity of resource exploitation, the relative emphases in habitat modification and plant exploitation, the nature of available food plants, or abiotic contexts, including fluctuating climates (especially temperature, rainfall and seasonality) and geophysical environments. Certainly differences of emphasis can account for the advent of grinding technology in Australia, and planting and

Fig. 7. View of the Huon Terraces, Papua New Guinea.

cultivation in some parts of New Guinea, although these were largely localised phenomena until the early or mid-Holocene. Furthermore, some parts of northern Sahul and Near Oceania were subject to external influences, such as the mid-Holocene advent of Austronesian language-speakers (Kirch, 1997), but people living in these regions may well have been connected to others living in regions to the west before this time as well.

The development of very distinctive lifeways across Sahul and Near Oceania during the Holocene reflects the accumulation of differences of emphasis through time. Here, differences of kind are relatively recent phenomena; even in New Guinea, there was no crossing of the Rubicon (following Bellwood, 2005: p. 25), namely a conscious decision borne of, or resulting in, necessity that led to a dependence on agriculture. Rather there are strands of different, but originally similar, activities across the continent. Through time, people began to emphasise certain types of activity in various locales and to bundle constituent practices in different ways. In several regions of Australia, resource intensification in the landscape (Hallam, 1989; Yen, 1989) predominated, while domiculture (Hynes and Chase, 1982), replanting of viable plant parts during harvesting (Gott, 1983) and incidental planting were regionally important. By contrast, in New Guinea, vegetative propagation and transplanting did become dominant activities across most of the island during the Holocene. Thus, through social agency over tens of millennia, what originally started as differences of emphasis yielded cumulative effects and differences of kind in terms of landscapes, plant management and lifestyles.

5. Conclusions

In terms of understanding how people colonised Sahul, as well as Near Oceania, the model of plant exploitation presented here shows how generalist sets of practices were tailored to different regions and biotic resources. Generalist behaviour is clearly exhibited by colonists through their relatively rapid occupation of Sahul and Near Oceania, including a broad range of climatic zones. Admittedly, the resolution of millennial-scale dating limits the interpretation of human adaptive processes operating over annual or decadal timescales, but such constraints apply to all attempts to understand human behaviour in the early years of human occupation of Sahul. Thus, the Sahul data provide an analogue for regions to the west; similar generalist adaptive practices most probably characterised the diffusion of people from Africa to Southeast Asia, with potentially similar patterns of coastal and inland occupation.

We draw on highly fragmentary data from Australia, New Guinea and Near Oceania to sketch how plant exploitation changed from the Pleistocene to the early Holocene. The archaeobotanical record of plant exploitation on Sahul during the Pleistocene is extremely patchy and fragmentary. Patchiness does not reflect an absence of suitable sites – over 70 pre-date 20 ka BP – or techniques, but a lack of methodological rigor. Early sites continue to be investigated, but few have been subject to even quasi-systematic archaeobotanical investigation, whether macrofossil (e.g., seeds, nuts and plant parts) or microfossil (e.g., phytoliths and starch grains). This is a critical direction for future research, given the demonstrated value of such mixed-method approaches at Pleistocene sites in Indo-Malaysia (Niah – Barton and Paz, 2007) and Australia (Cuddie Springs – Fullagar et al., 2008), as well as at Holocene sites in New Guinea (Kuk – Denham et al., 2003) and Australia (northeastern Queensland – Cosgrove et al., 2007).

We develop a heuristic framework to illustrate the bundling and transformation of plant exploitation practices in tropical regions of northern Australia and New Guinea during the Holocene. Recent differences in forms of plant exploitation in Australia and New Guinea originated through the accumulation of different emphases rather than being borne of a fundamentally different way of living in the world. We do not deny difference in the recent past or present, for it is certainly there, but we are guarded in extrapolating differences of kind into the more distant past. The heuristic model advocated here, although at an embryonic stage of development and requiring elaboration in terms of faunal exploitation, shows how generalised practices and technologies were applied following colonisation to the diverse climogeographic regions of Sahul and were transformed through time. After tens of millennia, these common practices were varyingly bundled by people living in specific locales to create regionally variable emphases in habitat modification and plant exploitation. The model is socially, geographically and historically embedded. Transformations predominantly reflect differences of emphasis in the bundling of common, or similar, constituent practices, which over extended periods of time led to major cumulative effects – including demographic, environmental, social and technological – that can be arguably characterised as differences of kind. These differences of kind with respect to plants are most marked and regionally variable in the Holocene.

6. Future research priorities

Although essential to clarifying the chronology of when people arrived in Australia, certain early sites should be targeted for future research because of the potential to illuminate the lifestyles of early colonists. We currently know almost nothing about early colonist behaviour beyond palaeoecological evidence of vegetation change and burning, sparse well-dated stone tools and associated residues, and circumstantial and highly selective arguments regarding putative megafaunal exploitation (Roberts et al., 2001). The earliest direct evidence of plant exploitation occurs around 30 ka BP in Australia and New Guinea. Consequently, our first priority is to investigate sites that greatly broaden our understanding of how early colonists lived. Second, we need to apply archaeobotanical techniques more systematically to sediments, particular artefact classes, and indeed to flaked stone assemblages.

An ideal candidate site for large-scale archaeological-led, multidisciplinary investigation is the raised coral terraces of the Huon Peninsula. This region has been subject to tectonic uplift since long-before human colonisation (Chappell, 1974; Fig. 7). Punctuated uplift separates periods of more extended stability for at least the last 45 ka BP during which people occupied the coast. These occupations are preserved on sequentially raised reefs that form discrete land surfaces, several of which are sealed beneath tephra. Previous archaeological surveys and small-scale excavations have yielded three waisted axe blades buried within a tephra at Bobongara that are associated with early colonisation (Groube et al., 1986). The terrace associated with the earliest inhabitants warrants much greater investigation than the cursory excavations to date, particularly given that the former land surface is sealed beneath a tephra. Previous surveys have recovered over 70 waisted and tanged implements in the vicinity, with even superficial survey turning up a specimen in an adjacent creek bed. Consequently, sites such as Bobongara on the Huon Terraces, which have been subject to uplift and burial beneath tephra, have enormous potential to shed light on the history of human colonisation of Sahul and, by inference, the diffusion of people across Southeast Asia.

Furthermore, variously flaked, edge-ground and waisted axes/hatchets have been found in early Australian contexts, e.g., one specimen dated to more than 31,900 + 700/−600 uncal BP (SUA 2870) at Sandy Creek 1 (Morwood and Tresize, 1989). Axes/hatchets/adzes were used for a variety of tasks throughout Sahul, often have stylistic significance, feature diagnostic usewear, and also provide an ideal class of artefact (along with grinding stones) for future research of plant residues (including resin, phytoliths and cellular tissue) likely to be embedded along used edges and surfaces in contact with hafts. Preliminary study of axes/hatchets/adzes from excavated and other museum collections indicate use residues are likely to be preserved in sufficient abundance for taxonomic identification of plants and direct dating of plant processing tasks. The investigation of residues and usewear on previously and newly excavated artefact assemblages has enormous potential to illuminate how the first colonists to Sahul used plants and adapted to diverse environments.

Acknowledgements

The authors would like to thank Peter Kershaw, Matthew Coller, Richard Cosgrove and Nicky Horsfall for providing information and addressing queries for this paper. A cursory survey of the Bobongara vicinity on the Huon terraces was undertaken in 2001 by Nick Araho of the Papua New Guinea National Museum and Art Gallery with Tim Denham. Especial thanks to Kara Rasmanis, School of Geography and Environmental Science, Monash University for diligently producing the graphics for this paper.

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