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Agricultural emergence and transformation in the Upper Wahgi valley, Papua New Guinea, during the Holocene: theory, method and practice

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Abstract: A practice-based method is advanced to understand the emergence and transformation of agricultural practices in the Upper Wahgi valley during the Holocene. Conceptually, practices represent the nexus of human–environment interactions, as well as of structure–agency relationships, while methodologically, they are the visible remains – whether encountered directly through archaeology, or inferred through palaeoenvironmental proxy – of people living in the past. Multidisciplinary information from the Upper Wahgi valley is used to reconstruct layered practices of plant exploitation across the landscape through time; the intention is to spatialize, temporalize and humanize information often represented chronologically and technically. Practice-oriented interpretations clarify, interrogate and amplify existing multidisciplinary records of the past and shed new light on how the earliest agriculture was originated and transformed in the New Guinea highlands during the Holocene.

Key words: Early agriculture, plant exploitation, landscape, practice, transformation, spatiality, temporality, human–environment interaction, Holocene, Papua New Guinea.

Introduction

Debates about early agriculture often become embroiled in terminological and substantive debates about what does and does not constitute evidence of agriculture in the past (see Harris, 1996, 2007; Smith, 2001). In an attempt to develop a more flexible and contextual understanding of agriculture relevant for different regions of the world, a contingent conceptual framework has been proposed in which multiple lines of evidence are compared against ethnographic accounts of different forms of plant exploitation for a given region (Denham, 2005a, 2006, 2007a). The term ‘plant exploitation’ is a generic term to connotate any form of people–plant interaction and is used here to refer to the exploitation of plants for food, whether as part of the most extensive foraging practices or the most intensive forms of systematic agriculture (Harris, 2007). Plant exploitation has traditionally been examined through two entwined themes: the manipulation of plant resources and the transformation of natural to artificial ecosystems (after Harris, 2007; also see Yen, 1989; Terrell et al., 2003; Kennedy and Clarke, 2004). In this paper, a similar dual approach is adopted: a focus on the spatial and temporal bundling of practices that are constitutive for different forms of plant exploitation; and, the effects of these practices, and the forms of plant exploitation they comprise, upon landscape formation in the past.

The intention is to unpack monolithic categories such as foraging, swidden cultivation and intensive cultivation as they are applied to the history of plant exploitation in New Guinea. The analytical focus is upon the continuities and discontinuities between forms of plant exploitation in space and time, and to show how they emerge and transform depending upon the ways in which constituent practices are ‘bundled’, or deployed in conjunction with one another, by people living in a specific landscape in the past. These ideas are applied to the multidisciplinary record from the Upper Wahgi valley and are intended to shed light on the transition to early agriculture and subsequent agricultural transformations during the Holocene.

The Upper Wahgi valley

The Upper Wahgi valley has been a focus of multidisciplinary research – principally archaeology, geomorphology and palaeocology – for over 40 years. In the 1960s joint palaeoecological and archaeological research was undertaken at Warrawau to investigate vegetation history (Powell, 1970) and the antiquity of agriculture in the highlands (Lampert, 1967; Golson et al., 1967; Golson, 2002; Figure 1). This multidisciplinary character has pervaded subsequent projects in the region, especially intensive research at Kuk Swamp in the 1970s and 1990s (Golson, 1977a, 1996 and...
Figure 1  Depictions of: (a) significant archaeological and palaeoecological sites on the island of New Guinea; (b) significant archaeological and palaeoecological sites in the western highlands of Papua New Guinea (shaded box in (a)); (c) the relative locations of Ambra, Kuk, Warrawau and Wurup sites in the Upper Wahgi valley; and (d) the relative locations of Kuk, Warrawau and Wurup sites along an altitudinal transect from the floor to upper walls of the Upper Wahgi valley.
Denham, 2003a, respectively). The resultant corpus of research is unmatched in New Guinea and is of global significance for understanding the emergence of early agricultural practices on the island (Golson and Hughes, 1980; Golson, 1991a; Hope and Golson, 1995; Neumann, 2003; Denham et al., 2003; Sandweiss, 2007).

One particular landscape of the Upper Wahgi valley has a dense and complementary coverage of sites variably subject to archaeological, geomorphological and palaeoecological research (Figure 1c,d). The multidisciplinary findings at these sites have been woven together to reconstruct multilayered phases of plant exploitation across the landscape from the Pleistocene to late Holocene (see below). The multidisciplinary findings comprise:

1. archaeological investigations of wetland manipulation and cultivation from the early and mid Holocene at Kuk and Warrawai, respectively (Golson, 1982; Denham et al., 2003);
2. palaeoecological reconstructions at Kuk, Warrawai and Lake Ambra that together cover the last 30,000+ years (Powell, 1970, 1982; Denham et al., 2004a);
3. archaeological excavations of occupation sites along an altitudinal gradient in the Wurup valley – Manim (1770 m), Kampaq (2050 m), Etpiti (2200 m) and Tugeri (2450 m) (Christensen, 1975; Aplin, 1981; Mangi, 1984; Donoghue, 1988, 1989); and,
4. geomorphological interpretations of catchment and slope erosion deposition rates at Kuk and Manim, respectively (Hughes, 1985; Hughes et al., 1991).

This landscape extends from the valley floor at c. 1500 m a.m.s.l. to the upper valley walls above 2400 m. The landscape comprises wetlands, the Wahgi River and its drainage network, gentle valley slopes and steep valley walls. These landforms sustain diverse wetlands, the Wahgi River and its drainage network, gentle valley slopes and steep valley walls. These landforms are suited to the cultivation of rice, vegetables and fruit trees. The Wahgi valley has a slight seasonal, lower montane humid climate dominated by local orographic effects (Powell, 1975; Kocher Schmid, 1991; Kennedy et al., 1988, 1989).

The average annual temperature is 19°C and annual rainfall is c. 2700 mm (Hughes et al., 1991: 229).

**Line of argument**

The conceptual, substantive and methodological implications of using a landscape and practice-based framework to understand past plant exploitation and early agriculture in New Guinea are summarized. The first section provides an overview of food supply and forms of plant exploitation across New Guinea today; this serves as a heuristic guide for understanding the diverse forms of plant exploitation in the past. In subsequent sections, the rationale for the conceptual framework adopted is indicated, the multidisciplinary and multiscale consilience of various lines of evidence are considered, and sequential reconstructions from the Terminal Pleistocene to late Holocene are presented for one landscape of the Upper Wahgi valley. The potential of a practice-oriented framework to clarify, interpret and amplify multidisciplinary records of past plant exploitation is then demonstrated. The concluding section highlights the general relevance of the approach proposed in this paper to debates concerning the emergence of agriculture and the transformation of agricultural practice.

**Food supply in New Guinea**

A starting point for understanding plant exploitation in New Guinea in the past is a consideration of practices across the island today. The ways in which people across New Guinea obtain food are highly variable (Powell, 1976; Kocher Schmid, 1991; Kennedy and Clarke, 2004), with similar but different variability likely to have characterized the past (Denham, 2005a). Mike Bourke has elicited several common elements within this variability.

[T]he essential components of food supply in New Guinea are:

- starch-rich staples,
- tree crops providing energy, oil and other nutrients,
- vegetables,
- sources of protein, primarily from hunting, fishing, and for the last few millennia the rearing of domesticated animals, and
- gathering of plants, fungi, grubs, honey and other resources.

(Based on Mike Bourke in Denham, 2007b)

Food supply across New Guinea is multifaceted and based heavily on plant exploitation, whether by horticultural groups (Bourke and Harwood, 2007) or ‘hunting and gathering’ groups, some of which are reliant on sago (Metroxylon sagu) and other tree crops (Roscoe, 2005). The importance of different food supply components can vary greatly, even between neighboring groups (Allen, 2005). However, dominant starch-rich staples tend to vary with altitude, whereas the significance of tree crops, hunting and gathering activities is dependent upon access to forest.

In the lowlands (below 600 m), major staples vary between taro (Colocasia esculenta), sago and bananas (Musa spp.), with yams (Dioscorea dumetorum) as major supplements in some areas. Tree crops are increasingly important for caloric and nutritional needs, especially coconut (Cocos nucifera), breadfruit (Artocarpus altilis), galip (Canarium indicum), Barringtonia spp. and Terminalia spp. Hunting, gathering and fishing provide abundant and regular sources of protein.

Moving out of the lowlands into the highland fringes (600–1200 m), groups cultivate taro, which is increasingly being supplemented by sweet potato (Ipomoea batatas) as the major staple, supplemented by bananas (variably significant), sugarcane (Saccharum officinarum) and yams. Diets are enhanced by mixed, intercropped and multiplanted, vegetable gardens. Tree crops, primarily marita (Pandanus conoides) and breadfruit, as well as hunting and gathering, are major and regular contributors to diet.

People living in the main highland valleys (primarily 1200–2000 m), such as the Upper Wahgi valley, practice intensive wetland and dryland agriculture on the valley floors and slopes. A large percentage of caloric intake was traditionally derived from taro, although in recent centuries this crop has been supplanted by sweet potato. Bananas, sugarcane and the greater yam (D. alata) are minor to medium contributors to diet in the highlands today, although they would have been more important prior to the introduction of sweet potato. Starch-rich crops are supplemented by mixed vegetables – usually planted in separate plots, house gardens or sometimes intercropped – and protein from intensively reared pigs (Sus scrofa). Gathering, hunting and tree crops, other than Pandanus spp., are minor and infrequent components of diets for people living on the floors of major intramontane valleys, largely owing to a lack of access to primary forest; although this varies spatially and through time depending upon residence, forest cover and social networks. For instance, for people living on the floor of the Upper Wahgi valley, nutritious Pandanus spp. in high altitude forests are less than one day’s walk, while abundant arboreal resources in the lowland rain forests are only a couple of days walk distant in the Lower Jimi valley.

**Practices in the landscape: a conceptual tool**

For conceptual, substantive and methodological reasons, the landscape is a suitable unit of analysis relevant to understanding plant
exploitation in the Upper Wahgi valley during the Holocene. Theoretically, landscapes are a realm of lived experience; people inhabit places that are not just physical, but are also imbued with meaning (David, 2002). Methodologically, multiple proximal archaeological and palaeoenvironmental studies facilitate the reconstruction of relatively fine-tuned spatial scenarios for people’s use of this landscape through time (Denham, 2003a). Substantively, people in New Guinea continue to conduct diverse and spatially scattered forms of plant exploitation across diverse habitats in the landscape; this can range from intensively cultivated wetland and dryland gardens to extensive gathering in stands of secondary and primary forest (Kennedy and Clarke, 2004).

If the landscape represents a ‘human-scale’ of lived-in places, how do we begin to understand people living in a past landscape? The starting point advocated here is the concept of ‘practice’ (Bourdieu, 1990; Barrett, 1994). Practice refers to customary behaviour or habitual activity. Practices are what people do, or did, and in this case are the multilayered constituent practices of food procurement, principally plant exploitation, across the Upper Wahgi valley. Higher-order activities, such as cultivation, agriculture or foraging, that represent the bundling of lower-order activities could also be referred to as a ‘practice’, but here for heuristic purposes are referred to as forms of plant exploitation.

From one standpoint, practices are the nexus of human–environment relations. The concept of practice reconciles established sets of dichotomies (Figure 2A) because it marks the intersection of social life with the biosphere and geosphere. Practices are structured by the environment within which they occur, while simultaneously acting upon and changing that environment. Methodologically, practices in the past can be inferred relatively directly from archaeological remains; they can also be inferred indirectly through the interpretation of palaeoenvironmental proxies – such as charcoal, phytoliths, pollen, sediments and so on – which represent past practices and their effects in conflated form.

To exemplify, archaeological evidence of past plant exploitation and cultivation practices at Kuk has been instrumental in clarifying often equivocal palaeoecological evidence of landscape transformation and archaeobotanical evidence for the presence and use of food plants (Denham, 2007a). For instance, archaeology documented artificially constructed mounds dating to 7000–6500 cal. BP on the wetland margin. Some fills between these mounds contained anomalously high *Musa* spp. banana phytoliths, while palaeoecological evidence showed a dramatic transformation of the landscape to grassland at this time (Denham *et al.*, 2003, 2004a). In this context, the archaeological evidence is crucial to grounding archaeobotanical and palaeoecological interpretation; together, these lines of evidence suggest mounded cultivation of crops with different edaphic requirements on the wetland margin within an anthropic landscape transformed to grassland and maintained by periodic burning. Such practices are consistent with those anticipated for agriculture in the highlands of New Guinea in the present or the past.

From another standpoint, practices are a manifestation and nexus of more abstract structure–agency dichotomies (Figure 2B). The degrees to which someone’s actions in the past, as in the present, were a product of structural determination (whether social, economic or mental), dispositions or individual improvisation are uncertain; initially all we know is that something happened. The ultimate cause why something happened often remain hidden for an event in the present, let alone something that occurred millennia in the past. In this case, the concept of practice reconciles established dichotomies in social theory and can be used to draw a clear distinction between what happened in the past and more speculative interpretations of why something happened.

To exemplify, in trying to explain why people did something in the past – whether in terms of what caused something to happen or in terms of what it meant to people in the past – we are continually drawing on our own frames of reference about how people behave and what governs that behaviour, ie, we continually fall back on patterns of thinking derived from our understanding of the world today. Consequently, we populate the past with *Homo economicus* and *H. ecologicus*, such as resource maximizers and optimal foragers...
At finer millennial to submillennial scales there are also rapid and potentially significant climate shifts experienced within the highlands of New Guinea, however the data are not well developed for this region at this resolution. As yet it remains unclear as to whether or not the impact of rapid and potentially global climate shifts recorded in the North Atlantic, known as Heinrich events (H4–H1 and the YD Younger Dryas; Figure 3), were significant in the New Guinea highlands. There is no consistent indication of a correlation between these events and the regional palaeoclimatic proxies illustrated here, though Turney et al. (2004) suggest that warmer and wetter conditions may have occurred during these periods at Lynch’s Crater in northern Australia during at least some of these events. The mechanisms for climate connections between the North Atlantic and equatorial Western Pacific remain elusive.

The implications of these finer-grained climatological processes have not yet been fully incorporated into accounts of people’s adaptation to environments from the Pleistocene to present in New Guinea or elsewhere. As well as the potential importance of Terminal Pleistocene climatic variability for plant domestication (eg, Hillman, 1996), insolation-driven changes in strength of seasonality over millennia will have had major implications for plant phenology and resource availability. Consequently, the ways people exploited and managed plants could have been qualitatively different in the Pleistocene than in the Holocene. Furthermore, the intensity, periodicity and duration of ENSO events since the Pleistocene would have variably sensitized different types of environment to human activities and spurred forms of plant management resistant to such interannual, or potentially more continual (Haberle and Chepistow-Lusty, 2000), perturbations.

At an intermediate landscape scale, palaeoecological records from the Upper Wahgi valley allow an assessment of changes in vegetation history through time and the interpretation of proxies inferred to be representative of human activities from the Pleistocene to the present (Figure 4). Taken together, pollen records from Kuk Swamp (5A, A10 f/g, and Kundil’s Section), Draepi-Minjigina, Lake Ambra, and Warrawa Plantation (Manton’s, M1) in the Upper Wahgi Valley document vegetation change from before 32 000 BP through to the present. Although representing variable periods and locations, the six records show that prior to 21 000 BP the valley floor was covered in almost 100% mixed montane forest, with little or no evidence for disturbance (Zone I), despite significant evidence for rapid climatic change at millennial timescales being evident throughout this time period. The period from 21 000 to 7000 BP is the most dynamic in terms of vegetation change (Zone II), including shifts in forest composition towards a greater secondary component (represented by light-demanding species including *Trenna* sp., *Acalypha* sp., *Macaranga* sp. and *Dodonaea* sp.) punctuated with burning events and grassland expansion. This occurs at a time when palaeoecological indicators point towards rapid and high-amplitude changes in temperature and precipitation, particularly extended dry and high ENSO frequency events, at millennial timescales. By c. 7000 cal BP the records show that grasslands had expanded significantly under the influence of burning and presumably forest clearance activities. The composition of remnant valley forests had also changed towards much greater representation of secondary forest taxa, implying a shift towards increased forest species’ turnover through time. This process of punctuated forest loss, burning and changing forest composition continues through to the late Holocene, suggesting a mosaic and time-transgressive pattern of forest–grassland dynamics, that persists through to the present (Zone III).

At the most local scale, archaeological records provide qualitative and specific information for plant exploitation on wetland margins and for occupation of rock shelters over the last 10 000 years. In this part of the Upper Wahgi landscape, intermittent evidence of...
plant food production (wetlands) pre-dates semi-continuous periods of drainage from c. 4000 cal. BP, although evidence of plant food consumption (rock shelters) is relatively continuous (Christensen, 1975; Donoghue, 1988, 1989). At wetlands, manipulation and plant use date to 10 000 cal. BP at Kuk, with mounded cultivation dating to 7000–6500 cal. BP at Kuk and to c. 5000 cal. BP at Warrawau (Denham, 2003b; Figure 5). In the wetlands, the preserved archaeological evidence represents only short-lived and localized practices, perhaps of only a few years duration, even though similar practices were probably occurring across the valley from at least the earliest record onwards. For instance, mounds continue to be used for dryland cultivation in several regions of the highlands today (Waddell, 1972). By contrast, occupational data from rock shelters extends from c. 11 000 cal. BP at Manim, from

Figure 3  Comparative diagram showing regional palaeoclimatic proxies spanning the last 40 ka: (I) palaeohydrological data from the PNG and northern Australia, inferred from sediment, coral and pollen records (Haberle and David, 2004; Gagan et al., 2004; Turney et al., 2004); (II) SE Asia-Pacific charcoal anomaly curve (extended analysis from Haberle et al., 2001); (III) number of El Niño and La Niña events per 500 yr in an orbitally forced model of the tropical Pacific (Clements et al., 2000); (IV) modelled solar insolation variation in the tropics (Berger and Loutre, 1991); and (V) Lynch’s Crater trends in organic sediment humification (absorption) values and GISP2 δ¹⁸O values (Turney et al., 2004)
Figure 4  Diagram of summary arboreal pollen with Poaceae (pollen sum for all taxa based on total forest and woody non-forest taxa), charcoal particle counts (where available) and radiocarbon chronology (~ = inferred age) from four swamp sites in the Upper Wahgi Valley (32K BP to present). Pollen data redrawn and amended with permission from Powell (1984) (Kuk 5A and Kuk A10 f/g), Powell (1982: 219) (Draepi DR29), Denham et al. (2004a: figure 5) (Kundil’s Section), Powell (1982: 221) (Lake Ambra) and Powell (1970: figure 8.7) (Warrawau M1). Solid lines mark comparable pollen assemblages at the six sites based on pollen assemblages and correspond approximately to inferred ages given in the original texts: Zone I (before 21,000 cal. BP), Zone II (c. 21,000–7000 cal. BP) and Zone III (c. 7000 cal. BP–present). Note changing scale for % Poaceae and charcoal counts

4800 cal. BP at Kamapuk and from 2100 to 2500 cal. BP at Etpiti and Tugeri (following Christensen, 1975: 30–34). The chronology of rock shelter occupation occurs along an altitudinal cline, plausibly reflecting the increased altitudinal extension of forest disturbance and clearance for cultivation during the Holocene (Christensen, 1975: 35).

Whereas archaeological features and finds can be directly interpreted with respect to specific activities or events in the past, palaeoenvironmental records contain gross spatial and temporal information. Although lacking specificity, palaeoenvironmental records provide continuous or semi-continuous data that augment spatially and chronologically fragmentary archaeological records. For example, a major archaeological deficiency in the Upper Wahgi valley is evidence for practices occurring on drier parts of the valley floor and valley slopes. The absence of dryland evidence reflects poor preservation; valley slopes have been subject to millennia of erosion, pedogenesis and cultivation. Consequently, the nature of dryland practices in the past, especially patch creation and swidden cultivation, is inferred from a combination of: palaeoenvironmental data of vegetation history and erosion rates for specific catchments; archaeological finds of stone tool technology; and, wetland archaeological evidence of environmental manipulation and cultivation, some of which is thought to represent the extension of dryland practices.

How, though, are these climate, environment and people interactions, which have been considered chronologically above, manifest spatially across the Upper Wahgi landscape?

Representing past landscapes

A sequence of plant exploitation scenarios is presented for the Upper Wahgi valley landscape from the Terminal Pleistocene to the late Holocene. Multidisciplinary information from sites across the landscape (described above) is woven and interpreted to recreate multilayered practices of plant exploitation across the landscape through time. The intention is to spatialize, temporalize and humanize information often represented chronologically, quantitatively and technically, such as in archaeological, palynological and sedimentological records.

Terminal Pleistocene, c. 17 000–11 500 cal. BP

The inhabitants of the Upper Wahgi valley during the Terminal Pleistocene inhabited a largely forested valley floor, with a gradually decreasing proportion of upper montane forest (dominated by Nothofagus) and a correspondingly increasing proportion of mixed lower montane forest (with greater frequencies of Castanopsis-Lithocarpus) through time (Figures 6a and 7a). In addition to faunal resources, the landscape offered ready access to the nutritious members of the high-altitude Pandanus brosimos/twen/julianetii complex (Stone, 1982), as well as to diverse arboreal resources of the lower montane forests:

Besides Castanopsis itself, which produces prolific quantities of small nuts, Bulmer and Bulmer (1964: 69) list a number of other trees with edible nuts and seeds, including Elaeocarpus, Sloanea, Finschia, Sterculia and especially Pandanus ...; vines with edible fruits; many trees, shrubs and ferns with edible foliage; many kinds of edible fungi; and wild edible yam-like tubers, apparently of the genus Dioscorea. (Golson, 1991: 87)

Rather than merely passively gathering resources, people were already opening up patches in the forest using fire and arguably used stone tools to ring-bark and clear vegetation (after Groube, 1989). Although the evidence is scant, people plausibly focused on gaps in the forest canopy, such as those caused by tree-fall and...
landsides, as well as riparian and wetland ecotones, where resources may have been different and potentially more diverse than those found under the forest canopy (Denham and Barton, 2006: 256–59; also see White et al., 1970; Fairbairn et al., 2006).

Some gaps in the forest were maintained through fire and clearing, and patches of grassland formed, potentially adjacent to wetlands and along riparian corridors, due to localized and sustained forest disturbance. As patches became maintained foci of activity, so too the resources within those gaps – including herbs (Musa spp.), tuberous plants (potentially including taro and yams), grasses (Saccharum spp. and Setaria palmifolia), and a wide variety of leafy vegetables – were brought under increasing management. At this time, people are inferred to have engaged in extensive hunting and foraging activities to sustain broad-spectrum diets. Although often presumed to have been high, mobility may have been spatially variable, depending upon the veracity of contentious claims for two open settlements of Terminal Pleistocene antiquity in the highlands at Wañelek (Bulmer, 1991) and NFX (Watson and Cole, 1977). Although people may not have resided permanently within the Upper Wahgi valley at this time, there are many reasons to believe that mobile groups lived permanently within the forested interior of New Guinea during the Pleistocene (see Denham, 2007c).

**Early Holocene, c. 9000 cal. BP**

During the early Holocene, the floor and walls of the Upper Wahgi valley were carpeted with increasingly disturbed lower montane forests; mid to upper montane forest had retreated to the ridgelines, peaks and higher valley walls above 2000 m (Figures 6b and 7b). Forest disturbance was variable, producing a mosaic landscape with locally encroaching patches of grassland and secondary forest subject to more persistent disturbance using fire and stone tools.

Hypothetically, there is a relatively smooth set of transformations from gap exploitation to gap maintenance to patch creation (all characteristic of foraging) to plot preparation (characteristic of swidden-type agriculture). In the highlands, such transformations may have occurred during the early Holocene, if not before. Patch creation and swidden cultivation mimic gap exploitation and maintenance in many ways, including: spatially focused but temporally transient exploitation; short-duration plant exploitation prior to revegetation; juxtaposition of plants with different structural properties, ie, trees, vines, herbs, shrubs and grasses; and, use of fire and tools (stone and wooden) to foster favoured plant growth (Denham and Barton, 2006: 258–59).

The transformation from gap maintenance to patch creation is marked by the deliberate clearing of a space within the forest, and plausibly within grasslands, to promote the growth of favoured plants. Groube (1989) has argued that people mimicked gaps formed by landslides, tree fall and fluvial processes through the artificial creation of patches using stone tools and fire from initial settlement over 40,000 years ago. Certainly palaeoecological records in the highlands, including the Upper Wahgi valley, signal anthropic disturbance of forests using fire during the Pleistocene (Haberle, 2007).
Figure 6  Spatial scenarios of landscape change through time: (a) Terminal Pleistocene, c. 12 000 cal. BP; (b) early Holocene, c. 9000 cal. BP; (c) mid Holocene, c. 6500 cal. BP; and (d) late Holocene, c. 2500 cal. BP
Through time, and following the digging up of useful plant parts – perhaps with the careful replacement of viable plant parts to ensure resource continuity – the range of activities occurring in patches increased and became more systematic. The systematization of burning, clearing and digging may in turn mark the difference between patch creation and plot preparation.

Although associated with other practices, including staking and plot preparation, another major difference between swidden cultivation and patch-based foraging in New Guinea is an increasing dependence upon the vegetative propagation of starch, fat and protein-rich plants, as well as leafy vegetables, and the transplantation of wild and feral seedlings, in conjunction with the continued tending of pre-existing stands. Planting is claimed to have a Pleistocene antiquity in Melanesia (Yen, 1996) and has been suggested as a means through which some bananas (of Musa section), taro and some yams moved from the lowlands to the highlands of New Guinea in the early Holocene (Yen, 1995; cf. Denham et al., 2004a: 852). The archaeobotanical record indicates the processing of taro and yam at Kuk from 10000 cal. BP (Fullagar et al., 2006). As well as becoming increasingly focused on patches and swidden plots, broad-spectrum plant exploitation continued across the landscape through a multitude of foraging and gathering practices.

As plant exploitation became more focused on maintained patches and swidden plots, people’s mobility may have decreased. Even though they need not have lived a sedentary life, people’s general mobility may have decreased in order to invest more time and labour in the maintenance of increasingly important and spatially fixed resources. People continued to engage in extensive activities, such as the foraging evidenced by the Pandanus antaresensis-dominated archaeobotanical assemblage at Manim (Donoghue, 1988), as well as long-distance and long-duration hunting and foraging expeditions to higher and lower altitudes, but a greater percentage of their time was plausibly spent managing, harvesting and consuming resources within more limited areas around maintained patches and swidden plots. A more intensive spatial focus was presumably accompanied by a more localized sense of territoriality, i.e., a social identity manifest increasingly locally within the landscape.

**Mid Holocene, c. 6500 cal. BP**

By approximately 6500 cal. BP, forests of the Upper Wahgi valley had been severely degraded; grasslands predominated on the valley floor (as recorded at Kuk; Denham et al., 2004a) with disturbed forests along the valley walls (inferred from Warrawau; Powell, 1970) (Figures 6c and 7c). Palaeoecological records at Kuk suggest persistent and increasing disturbance of forests using fire from the early Holocene, presumably associated with swidden cultivation, and more ubiquitous disturbance within the Upper Wahgi valley and other highland valleys from the mid Holocene (Haberle, 2007). The archaeobotanical assemblage at Manim marks a dramatic shift at this time in the nature of plant use, from a predominance of *P. antaresensis* to a broad variety of – as yet – unidentified plants and plant parts (Donoghue, 1988: 71–78; subject to ongoing research). Furthermore, the adoption of edge-ground stone tools from this time would have greatly facilitated forest clearance (Golson, 2005: 467–69).

As well as engaging in extensive foraging and gathering, and swidden cultivation, the earliest evidence of more intensive forms of plant exploitation emerged during the mid Holocene. The bases of mounds used for cultivation date to 7000–6500 cal. BP along the wetland edge at Kuk, with more recent pre-c. 4500 cal. BP finds at Warrawau (Golson, 2002) and Mugumamp (Harris and Hughes, 1978). Although preserved at wetlands, mounded cultivation may also have occurred in dryland locations at this time. The advent of intensive forms of cultivation required only a minor technological innovation, namely, the piling up of earth to form mounds. However, the effects of this innovation were enormous because of the resultant ability to cultivate plants with different edaphic requirements along wetland margins (Golson, 1977a: 617) and to potentially maintain cultivation of the same plot for several years, through rebuilding mounds with incorporated organic matter (after Powell et al., 1975: 11, 12). The adoption of mounding greatly

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**Figure 7** Altitudinal scenarios of landscape change through time: (a) Terminal Pleistocene, c. 12,000 cal. BP; (b) early Holocene, c. 9000 cal. BP; (c) mid Holocene, c. 6500 cal. BP; and (d) late Holocene, c. 2500 cal. BP.
expanded the capacity to produce food on valley floors increasingly dominated by grasslands.

During the mid Holocene, plant exploitation was extremely diverse and included gathering, patch creation, swidden cultivation and intensive forms of moulded cultivation. These practices all co-occurred across the landscape, with a gradual increasing reliance on plot cultivation as access to primary or disturbed forest became more restricted for groups inhabiting the valley floor. A greater reliance on plots, especially those potentially cultivated for several years continuously, would be associated with major social transformations, especially lower mobility, greater sedentism and greater territoriality. The intention is not to suggest that changes in production led to changes in the social milieu, rather that both were mutually transformative, mutually reinforcing and probably occurred simultaneously. Although not yet documented archaeologically, almost year-round occupation of settlements can be envisaged, sustained by near-continuous food production in the aseasonal climates of the Upper Wahgi valley.

**Late Holocene, c. 2500 cal. BP**

Following several thousand years of persistent forest disturbance for various forms of plant exploitation, the majority of the valley floor and slopes were degraded to grassland (Figures 6d and 7d). Only isolated pockets of disturbed forest survived within the valley, with stands of heavily utilized primary forest surviving on the higher slopes above 2000 m. The extensive grasslands carpeting the floor of the Upper Wahgi valley were periodically burned and would have been depauperate in large-to-medium sized mammals and edible plants (Golson, 1982: 127–28).

Within this highly degraded, but intensively settled landscape, people had less access to land for swidden cultivation and foraging. Although, these activities were still likely to be practiced by people living on the valley floor, they became increasingly reliant on intensive forms of dryland cultivation, plausibly using mounds and other forms of raised bed cultivation on valley slopes (Powell et al., 1975), as well as upon ditched field systems in the wetlands and eventually upon Casuarina tree-fallowing (Haberle, 2007). Several wetlands in the Upper Wahgi valley (Kana, Kuk, Warrayawu) and adjacent regions (Haepagupa, Tambul) were drained for cultivation, and some had already been periodically or episodically drained for centuries by 2500 cal. BP; the earliest wooden spade at Tambul and earliest ditches date to over 4000 cal. BP. BP in the region (Golson, 1997; see Denham, 2005b for review). Current evidence suggests ditch construction and associated wooden tools were indigenous inventions. The drainage of wetlands to create ditched field systems would have not only greatly increased the area available for cultivation, but the drained land would have been extremely fertile, particularly relative to heavily weathered valley slopes; amenable to cultivation for several years without fallow; and, relatively resistant to the increased frequency of El Niño-Southern Oscillation (ENSO)-induced droughts.

A near-reliance of valley-floor occupants upon semi-continuously cultivated plots in wetlands and on dryland slopes can be envisaged to have been accompanied by major social transformations. Decreasing individual and group mobility was accompanied and caused by many factors, including greater investments of time and energy in year-round cultivation – including the maintenance of dryland and wetland field systems – and the likely existence of highly territorial social groups. For example, the lack of access to forest was not solely a function of distance; people were potentially blocked by antagonistic social groups. The emergence of permanent settlements, territorial-based patrilineal descent groups and social dynamics, which have been documented ethnographically for this region (Strathern, 1971, 1972), may well have occurred at this time.

**Understanding plant exploitation in the past**

Although the interactions among climate, environment and people have been considered chronologically and spatially, little light has been shed on how agricultural practices were initiated and transformed in this region. The starting point below is to unpack plant exploitation practices across the landscape, establish a chronology of practices constituent for different forms of plant exploitation, and then suggest how forms of plant exploitation have been transformed through time.

**Unpacking plant exploitation across the landscape**

Food supply is multilayered and multiplastic; many agricultural peoples still engage in hunting, gathering and tree exploitation activities of variable significance for their diets. To illustrate, at approximately 2500 cal. BP, people in this region engaged in multiple forms of plant exploitation: foraging, patch disturbance, intensive dryland cultivation and intensive wetland cultivation (using ditch networks); each type of activity had its own spatiality or extension across the landscape (Figure 8). Spatiality of practice is socially embedded and necessarily leads to a consideration of broader social dynamics, which have only briefly been alluded to in the scenarios above, including identity, group structure, territoriality, mobility, settlement patterns and so on. Unfortunately, the archaeological record provides a very limited view of the broader social world in this part of the Upper Wahgi valley during the Holocene. Despite these deficiencies, it is possible to unpack each form of plant exploitation into constituent practices, establish chronologies for these practices, and to then show how they were bundled in space and time to initiate and transform agriculture in the past.

**Chronology of practices**

The practices constitutive for traditional forms of plant exploitation can be traced, or inferred, from archaeological and multidisciplinary lines of evidence from across the highlands (Figure 9). The range of practices cuts across traditional terminological distinctions of gathering and horticulture because, in many cases, the practices presented are constitutive for multiple forms of plant exploitation. This perspective provides a framework to interpret how agricultural practices arose from pre-existing forms; the likely timing and nature of the earliest agriculture in the region; and, gaps and inconsistencies in the multidisciplinary record. First, from this perspective, the derivation of agriculture and subsequent transformations from pre-existing forms of plant exploitation are not necessarily major thresholds (contra Harris, 1996, 2007; Bellwood, 2005), even if subsequent social and environmental effects may be immense. In the Upper Wahgi context the transition from foraging to a form of agriculture (probably of swidden-type) is essentially marked by two shifts: from forest disturbance (gap maintenance and patch creation) to plot preparation; and, to an increasing dependence upon the vegetative propagation of starch, fat and protein-rich plants and transplantation of leafy vegetables. Both shifts are of emphasis rather than of kind. The first comprises analogus practices differentiated by an increasing systematization of burning, clearing and digging. The second constitutes an increasing dependence, rather than the initiation of planting *per se*, given that planting is considered to have a long antiquity in Melanesia originating in the Pleistocene (Yen, 1996).

Second, an evaluation of the chronology provides plausible time frames for different forms of plant exploitation, which are effectively bundles of co-occurring constituent practices, even when direct archaeological evidence for those activities is lacking. For example, the chronology can be used in conjunction with palaeoecological and indirect forms of archaeobotanical evidence.
to argue for swidden cultivation in the Upper Wahgi valley during the early Holocene, even though direct archaeological evidence of a swidden-type plot is debatable. Thus, a form of agriculture can be inferred at an earlier time than the unequivocal multidisciplinary evidence of mounded cultivation at 7000–6500 cal. BP (Denham et al., 2003, 2004a).

All constituent practices constitutive for shifting, or swidden cultivation date to at least 7000–6500 cal. BP; these include burning, forest disturbance, digging, tuber exploitation, staking, plot preparation and planting. The lack of archaeological sites of swidden plots is probably a product of preservation; shifting cultivation is likely to have been largely confined to dryland slopes subject to millennia of erosion, pedogenesis and cultivation that have removed traces of earlier activities. One exception to this archaeological deficiency are 10 000 year old remains on slightly higher ground along the wetland margin at Kuk, which have been variably termed plant exploitation or agriculture (Denham et al., 2004b: 274–78).
associated archaeobotanical remains and palaeoecological signals, are consistent with those anticipated in a swidden-type plot worked on a wetland margin during a short period of locally drier conditions (see varying arguments in Denham et al., 2004b: 274–78; Denham, 2005a, 2007a; Golson, 2007).

From 10 000 cal. BP, archaeobotanical evidence indicates that at least three potential staples were present or being used in the Upper Wahgi valley: bananas of Musa section, taro and a yam (Denham et al., 2003; Fullagar et al., 2006). If previous interpretations are correct, and at least bananas of Musa section and taro are of ultimate lowland derivation, then their altitudinal expansion would most likely be a product of planting (following Yen, 1995; Hope and Golson, 1995). However, alternative non-planting scenarios most likely be a product of planting (following Yen, 1995; Hope and Golson, 1995). However, alternative non-planting scenarios can account for these plant distributions (Denham et al., 2004a: 852; Denham and Barton, 2006: 258–59). Palaeoecological evidence of the dryland sphere indicates sustained disturbance using fire of lower montane rain forests from at least 10 000 cal. BP in the Upper Wahgi valley, with concomitant and spatially variable transformations to a mosaic of primary forest, disturbed forest and grassland (Denham et al., 2004a: 845–48) and increased erosion rates in the Kuk catchment (Hughes et al., 1991). Such practices and signals are characteristic of environmental degradation under agriculture in many parts of New Guinea today and have been argued to be associated with similar activities from the early Holocene (Hope and Haberle, 2005: 546–47). In the absence of definitive evidence, but with strong independent lines of circumstantial evidence, an examination of the chronology of constituent practices intimates that a form of swidden-type cultivation occurred in the Upper Wahgi valley during the early Holocene, ie, from c. 10 000 cal. BP.

Third, the chronology can be used to interrogate and identify shortcomings of the multidisciplinary record. For example, the earliest wooden digging stick dates to c. 2500 cal. BP (Golson et al., 1967), whereas clear evidence for digging dates to c. 10 000 cal. BP and stone tools inferred to be used for digging date to over 25 000 years ago in the highlands (Bulmer, 2005). Although stemmed round-bladed stone implements, sometimes referred to as ‘hoes’, and other stone tools would have been used for digging, it is inconceivable that simple wooden tools were not used for planting and digging during the earliest types of swidden-type cultivation, if not before (Golson, 1977b). Certainly, wooden digging sticks are likely to pre-date wooden spades used for digging and maintaining ditches, the earliest of which is over 4000 years old. Thus, the chronology provides a useful framework to highlight deficiencies of record and can indicate whether the earliest finds of a given practice or technology – exemplified here with respect to wooden digging sticks – are yet to be found.

The chronological articulation of constituent practices and forms of plant exploitation enables the clarification, interrogation and amplification of the existing record. Three major methodological outcomes are advanced: a focus on the nature of transformation between different forms of plant exploitation; an approximate time frame for swidden-type cultivation in the highlands, potentially from c. 10 000 cal. BP; and shortcomings of the multidisciplinary record have been identified. In addition to its analytical value, the chronological depiction is a useful starting point to understand how constituent practices become bundled and transformed in time and space, ie, to understand the temporality and transformation of forms of plant exploitation through time.

**Temporality and transformation**

The temporal and spatial bundling of constituent (lower-order) practices to shape distinct forms of plant exploitation (higher-order) was, and still is, highly variable in different locales across New Guinea. The high spatial diversity of plant exploitation reflects complex, divergent and contingent bundling of different types of constituent practices – as well as plants and other resources – through time by people living in different landscapes. The spatial and temporal bundling of practice is heuristically depicted with reference to a modified version of Hagerstrand’s time-geography (after Hagerstrand, 1978); the ways in which constituent practices are bundled to form distinct forms of plant exploitation during the early to mid Holocene are illustrated with reference to the Kuk landscape (Figure 10).

The transformation and increasing multilayered character of plant exploitation during the Terminal Pleistocene and early Holocene is charted through time and across the landscape. The transformation of plant exploitation is clearly shown with respect to continuities from pre-existing forms, but with additional adoptions, whether of local or extralocal origin. The intention is not to suggest that multiple forms of plant exploitation arose through independent innovations in the Upper Wahgi valley or highlands, but to indicate the minimum practical or technical innovation required to transform one form of plant exploitation practice into another. This approach emphasizes the transformative nature of plant exploitation through time, rather than viewing forms of plant exploitation – including agriculture – as static, monolithic or complete entities.

The temporality of different forms of plant exploitation is not necessarily unidirectional and cumulative. Some activities, such as foraging, have an extremely long history, perhaps dating from first settlement at least 40 000 years ago (Groube, 1989) and continue to the present day. Similarly, some cultivation practices have considerable antiquity and continuity to the present, including moundified cultivation from 7000 to 6500 cal. BP and ditched field systems from c. 4000 cal. BP. Other practices are locally discontinuous, such as shifting cultivation that may have been initiated in the early Holocene but was now limited on the floor of the Upper Wahgi valley; although shifting cultivation remains common in many other parts of New Guinea.

![Figure 10 Temporality, bundling and transformation of plant exploitation in the landscape (adopting style of figure in Gregory, 2000: 831)](image-url)
The local abandonment of shifting cultivation in the Upper Wahgi valley can be attributed, speculatively, to two factors: a social constraint and a cultural preference. First, increasing territoriality towards the present, reflecting an increased association of identity with place and increased group differentiation, may have restricted access to the large tracts of land required to make shifting cultivation sustainable. Second, the replacement of large tracts of forest by grassland during the Holocene dissuaded people from swiddening – the labour required to clear plots in grassland is considered more arduous than clearing forest and may have contributed to the maintenance and intensification of cultivation in plots once established. Following the near-abandonment of shifting cultivation, people invested in intensive forms of semi-permanent dryland and wetland cultivation, which were eventually transformed into those recorded historically (Powell et al., 1975). In terms of the interpretative framework proposed here, although one form of plant exploitation was locally abandoned, constituent practices were maintained in another bundled form.

Implications for understanding early agriculture

Agriculture is often characterized in highly binary terms with reference to ‘hunting and gathering’ (see Harlan, 1995, for critique) and its development has been portrayed as being an ‘all or nothing’ lifeway, comparable with the crossing of the Rubicon (Bellwood, 2005: 25). The New Guinea evidence, as well as increasing bodies of evidence from Africa and the Americas, suggests that agriculture is a more porous concept that is diffuse in space and time (see Aplin, 1981, for critique). The New Guinea evidence, as well as increasing bodies of evidence from Africa and the Americas, suggests that agriculture is a more porous concept that is diffuse in space and time (see Aplin, 1981, for critique). The scenarios for the Upper Wahgi valley demonstrate the multilayered character of plant exploitation and early agriculture; practices are multilayered, have different spatial expressions across the landscape, and are variably important at different times in different places. For the Upper Wahgi valley in the past, and for New Guinea generally, there is no ‘one size fits all’ concept of agriculture. Practices are highly variable and many defy standard categorization (eg, Specht, 2003). The practice-based method outlined in the second half of this paper can be applied to characterize the spectrum of plant exploitation practices across New Guinea both for the past and the present; it can also be used to demonstrate how people in particular landscapes initiated and transformed agriculture through time.

The application of a practice-oriented approach emphasizes continuity and transformation through time, illustrated here with respect to a chronology of plant exploitation for one Upper Wahgi landscape and discussed in detail with respect to specific forms of plant exploitation. Notably, there are numerous continuities between shifting cultivation and some types of foraging practices, as well as between some intensive forms of cultivation, ie, mounding, and forms of shifting cultivation. These continuities are demonstrated through considerations of how constituent practices are bundled in space and time to form distinct forms of plant exploitation and how one form of plant exploitation transforms into another through the adoption of new – together with a reconfiguration of existing – constituent practices. Despite these continuities, there is nothing intrinsic to foraging practices in New Guinea that inevitably led to the development of agriculture. Rather, the agricultural history of the Upper Wahgi valley emphasizes the temporal contingency of various forms of plant exploitation, both in terms of constituent practices and in terms of how they become embedded in the socio-spatial construction of landscape.

The intention of this paper is to show that the emergence of early agriculture and subsequent transformations in agriculture through time are not necessarily dramatic events marked by significant thresholds, at least at the time that they initially occurred; although the unforeseen and cumulative consequences of these events can be enormous. Rather than thinking about foraging and agriculture in such monolithic terms, a practice-based approach brings forth the nuances and diffuseness of early and later agricultural history. As research continues in the Upper Wahgi valley, its agricultural history will undoubtedly become more complex and continue to shed light on issues of global relevance.

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