MONTANE AND ALPINE PEATLANDS OF NEW GUINEA.

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SUMMARY

Peatlands are extensive above 1000m in New Guinea and become the dominant substrate above 3000m in the subalpine. Swamp forest and grassy sedgeland predominate in the montane mires on swampy valley bottoms. Most mires are 5-10m in depth, with peat deposition spanning more than 30,000 years. In Papua New Guinea (PNG) there are 140,000 ha of montane peats and Papua (the Indonesian western half of the island) probably contains much more. Above 3000 m peat soils form under blanket bog on slopes as well as valley bases. Vegetation includes cushion bogs, grass bogs and sedge fens. On slopes, typical depths are 0.5-1m but valley bases and hollows contain up to 10 m of peat. The estimated extent is ca 1,750,000 ha in PNG and about 2,400,000 ha in Papua province. The stratigraphy and age structure of 45 peatlands or organic limnic sites above 750 m have been investigated since 1965.

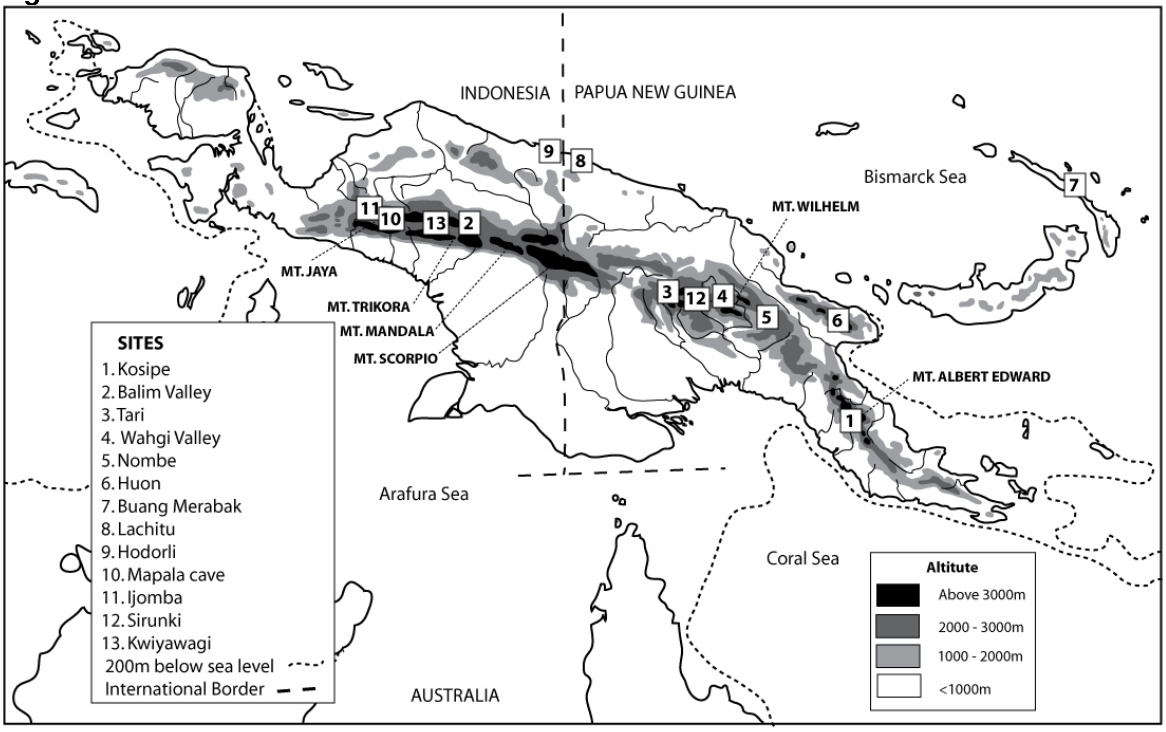
KEYWORDS: montane swamps, peat, vegetation change, New Guinea, fire history

INTRODUCTION

New Guinea is the largest, highest and wettest tropical island in the world with an area of 820,000 km^2 (including associated large islands of Papua New Guinea and the Indonesian provinces of former Irian Jaya). Peatlands occur at all altitudes owing to rainfall generally exceeding 2500mm yr^{-1} and very high cloudiness. Little work has been carried out on the stratigraphy of the lowland peatlands whose area has been estimated to range from 4.1-11.8 Mha (Maltby & Immirzi 1993, Radjagukguk 1997). Few have been cored, however, making the calculation of peat volume speculative. The situation is slightly better for upland peatlands, which include substantial topogenic mires and even large areas of moorland above 3000m. A sample of these have been probed and cored for palaeoecological study allowing estimates of depth, volume and current status to be made with slightly better confidence than for the lowlands.

The mountains in New Guinea consist of a central core of ranges trending NW-SE whose crests often exceed 3500m as well as lower mountain ranges closer to the north coast (Figure 1). Orographic rain from the SE Trades and easterlies affects both sides of the ranges but some of the intermontane valleys are drier and it is here that intensive agriculture occurs. At higher altitudes rainfall totals may level off but the tops are always cloudy and wet right to the highest peaks above 4750m (Prentice & Hope 2007).

Figure 1 New Guinea localities



The transition from lowland forest to smaller-leaved montane forests can be as low as 600m and is usually complete by 1000 m (Paijmans 1976). Often the transition occurs where clouds persistently form during the diurnal cycle as such areas have high humidity and lower radiation than the lowland plains. The second transition occurs above 2900 m where subalpine forests form a mosaic with grassland and sedgeland up to the tree line, which can be as high as 4000 m on limestones but 3700 m on less well-drained substrates. Areas above 3400 m have been affected by Pleistocene glaciation and a small ice cap occurs on Mt Jaya above 4600 m (Prentice *et al.* 2005).

Peatland extent.

Table 1 indicates the extent of peatlands and volume of organic matter in the mountains of New Guinea. Data for PNG were generated from PNGRIS GIS data on organic soils. The data in the table include, however, an estimate for the montane peatlands of Irian Jaya based on relative frequency of the swamp types compared to PNG. This is based on just a few stratigraphic investigations and some observations in the main range at 4 regions and reports from a fifth region. It can be seen that the montane peatlands, while extensive, are outweighed by the organic terrains of the high mountains which total an estimated 55,000km^2 above 3200 m. Peatland is estimated to be about 27% of this area and thus makes up much more of the wetland carbon store than the isolated montane swamps. A single area, for example, the 410km^2 wetlands east of Paniai Lake, however, may have much thicker peat than the average used here, so that the relative importance of the montane peatlands may increase with further research.

Table 1 Major peat-forming wetland classes in upland New Guinea

Dominant vegetation	Peat types	Altitude range (m)	Peat thickness (m)	Area (km^2)	Organic mass (Mt)
Montane swamp forest	Fibrous wood peat	500-3000	1.5-8.5	2900	640
Herbaceous floodplain swamps	Organic muds, fibrous peat, organic clays	750-2500	2.0	1700	690
Tall sedge-grass swamp	Fibrous peat, humic clays	500-3000	2.0-7.0	1540	390
Short sedge-grass fens	Humic peat Fibrous peat	2500-4500	1.5-5.5	1250	6100
Subalpine moorlands: e.g. Astelia-Gleichenia blanket bog, Hard cushion bog, Carpha fen	Humic and fibrous peats	2800-4200	0.8-2.0	14350	13610

MONTANE PEATLANDS

The peatlands below 2900 m depend on water inflows to maintain wet conditions and so depend on topography. Rivers often carry a huge sediment load and build levees that block off extensive wetlands on floodplains and abandoned meanders. Tall Grass Swamp, dominated by tall grasses such as *Phragmites karka* and sedges, often forms coarse fibrous peat intercalated with silt or clay. The fibrous peat may be several metres thick but more usually is only 1-2 m and not of great age. One example is the upper Wahgi River near Mt Hagen where mid-Quaternary volcanic lahars have blocked river valleys and extensive grass peatlands up to 15 m thick have formed in the last 30,000 years (P. Hughes pers. comm). Similar peatlands are also extensive along the Balim River in Papua and around lakes such as Paniai Lake. A swamp infilling an abandoned meander at Kelela in the Balim Valley contains 5 m of fibrous peat that has formed in the last 7000 years (Haberle *et al.* 1991).

A related peatland type occurs in topogenic lows and closed basins which are common in New Guinea owing to volcanism, tectonics and solution. Tall Sedge Swamp of *Machaerina, Isolepis* and *Eleocharis spp.* infills the basins, sometimes with grass (*Sacharum* spp.) present. Montane Swamp Forest of *Dacrydium nidulum, Dacrycarpus* and *Podocarpus* as well as *Pandanus* spp, Myrtaceae and *Castanopsis* are often present on the margins on thick peat. Lava-dammed basins near Tari in PNG (Haberle 1998) contain 100,000 year sequences of peat. Large examples include Kayamanda (Sirunki) Swamp (Walker & Flenley 1979) with more than 25 m of sediment dating back more than 35,000 years. At Kosipe Swamp at 1996 m a stream levee created a wetland about 40,000 years ago and this peatland expanded with a younger initiation date of 22,000 yr BP 4 km up valley from the original initiation point (Fairbairn *et al*. 2006). It now contains >6 m of peat over an area of 18 km^2. Landslides can dam valleys as at Nurank Swamp, at 2200 m in the central ranges of Papua New Guinea. Here *Sphagnum* and sedge peat form a 1 m mat over water above 8 m of lake sediment representing 4000 years of accumulation (Gillieson *et al.* 1990). Solution basins are also widespread in both limestone and ultramafic rocks, and many of these are infilled with peat. An example is 4 m of marginal peatlands near Anggi Gigi lake in Irian Jaya dating back 15000 years (Hope 2007).

Significant outcrops of fossil peat are known together with buried humic soils. A volcanic lahar dammed the Tambul valley near PNG where a 40 m section of peat is preserved that dates to around 50,000 years BP (Loffler 1982). Other peats formed under swamp forest and subsequently buried by outwash fans, occur in the upper Balim Valley near Kwiyawagi (Hope *et al.* 1993).

SUBALPINE PEATLANDS.

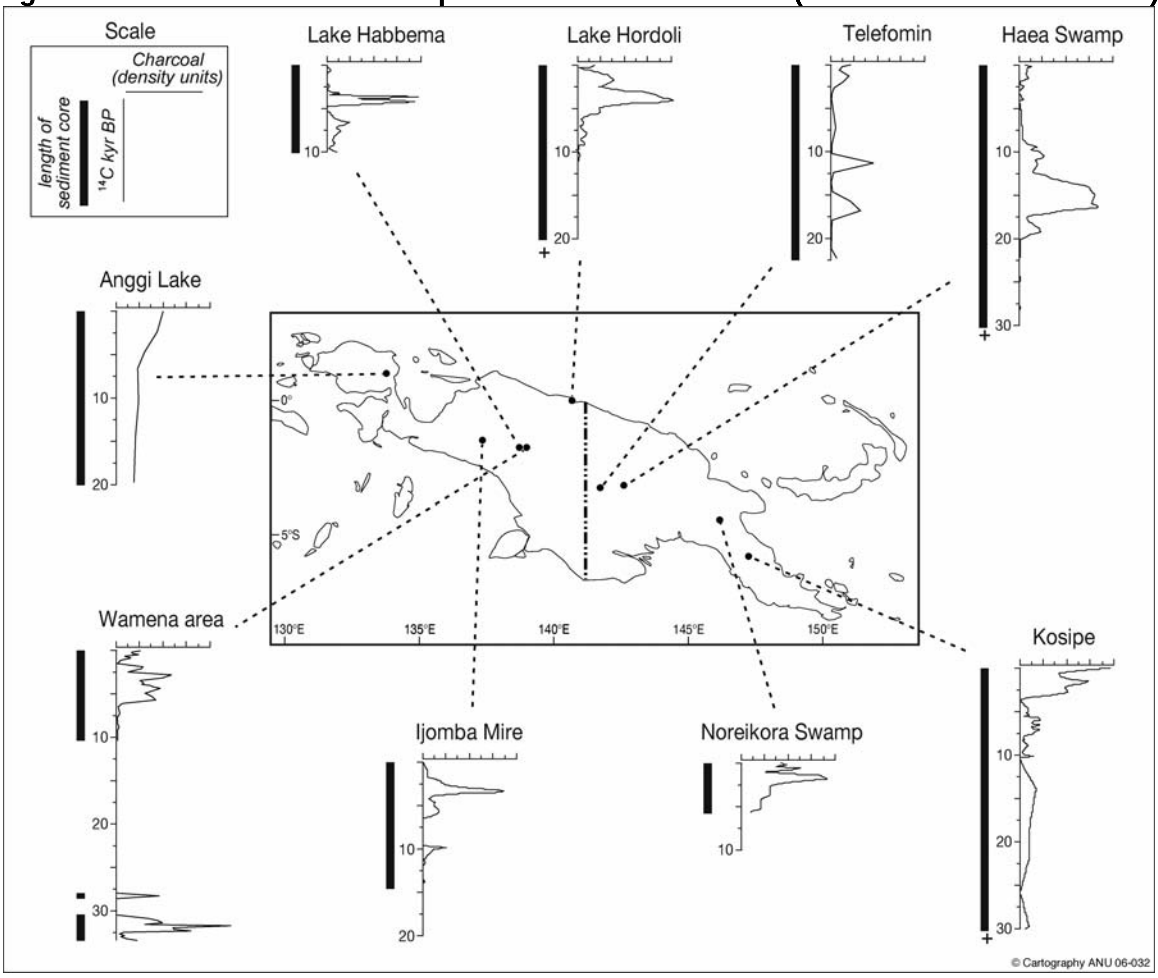
Around 2900-3200 m the mean temperature falls below 10ºC and organic decay is slowed to the point that soils become positive carbon accumulators. Plateaux and mountains with subdued relief such as the extinct Mt Giluwe volcano have substantial areas of blanket bog. In addition, glaciers covered about 2000 km^2 and left numerous topogenic hollows in cirques and moraine blocked valleys. The ecology of these peat forming communities has received more attention than lower altitude mires (e.g. Hope 1980) Topogenic peatlands often contain cosmopolitan peat forming species such as *Carex gaudichaudiana*. Sedge or grass fens with 3- 5m of peat are common on all mountains in formerly glaciated terrain. The high altitude sites analysed for pollen are listed by Prentice *et al.* (2005). An example on limestone terrain is Ijomba Mire on the Kemabu Plateau which was deglaciated ca 13,000 yr BP. At first the site was free draining but finally sealed with peat around 6000 years ago and has accumulated 3 m of peat under a mixed shrub-sedgeland since then.

On gentle slopes often bordering the topogenic mires, peat or organic soils have formed blanket bog under several moorland communities. These include a shrub bog of Ericaceae such as *Vaccinium* and *Rhododendron* species especially a large hummock former, *Rhododendron saxifragoides*. Hard cushion bog contains numerous herb and shrub components such as *Oreobolus*, *Plantago, Potentilla*, prostrate *Xanthomyrtus* and mosses. *Astelia papuana* and *Gleichenia vulcanica* also form distinctive cushion communities (Gibson & Hope 1986). At very high altitudes tundra-like communities form shallow peat soils, for example *Carpha alpina* and *Ranunculus saruwagetica* tundras (Wade & McVean 1969). On the wettest mountains, for example the granidiorite Mt Scorpio, slopes support 1-2 m of blanket peat under stunted open woodland, shrubland and fernland. To the southeast the climate is more seasonal and slightly drier so moor peat is less extensive and shallower.

MIRE DEVELOPMENT

The history of the subalpine mires reflects the glacial and post-glacial changes. At Komanimabuno at 2800 m, 3 m of grass-sedge peat accumulated under cold conditions from 22,000-12,000 years BP after which the site was invaded by swamp forest with a slower organic accumulation rate, presumably reflecting warmer conditions (Hope 1976). The glacial times seem to have allowed an extension down slope of moorland peat and humic build up as an organic-rich layer is preserved in soil profiles down to 2000 m as at Kosipe (Fairbairn *et al*. 2006). In contrast, the montane swamps have a wide range of ages related to the formation of basins by tectonic or other causes. Peat formed on volcanic lahars around Mt Hagen more than 50,000 years ago but the process was interrupted by human settlement after 9000 years ago (Denham *et al.* 2004). Fire became more prominent in some swamp pollen records after human occupation commenced about 35000 years ago (Fairbairn *et al.* 2006, Haberle *et al.* 2001) and disturbance becomes widespread in the Holocene (Figure 2). Even subalpine peatlands are burnt despite being distant from permanent settlement.

Figure 2 Charcoal records from peatlands in New Guinea (from Fairbairn *et al.* 2006)



Despite the high fire activity at the end of the last glacial period the driving force behind forest expansion into grassland overrides the persistence of fire activity such that, in all mire records that cover the early Holocene, we find swamp forest dominated by *Syzygium*, *Pandanus* and some gymnosperm taxa developed around wetlands in the valley floors. The relatively high biodiversity and resource value associated with swamp forests, including the high density of utilisable *Pandanus* species (*P. antaresensis, P. brosimos/julianettii* complex; Haberle, 1995) may have led to these environments being a focus of human activity throughout the Holocene.

The appearance and spread of "agriculture" in the highland valleys occurs about 7000 years ago (Haberle & Hope 2006). The earliest indications of ditching within a mosaic of forest and grassland around 9,000 BP (Denham *et al.* 2004) accord remarkably well with the transition to "modern" Holocene climates and points to the possibility that expansion of clearing and plant manipulation was partly environmentally controlled. By 7-6,000 years ago the lower parts of the major highland valleys were cleared and would have looked similar to their appearance in 1933 (minus sweet potato cultivation). It is possible that the early Holocene was a time of more reliable climates, the El Niño related drought and frost being much rarer (Groves & Chappell 2000). This would have rewarded experimental taro and banana planting and water manipulation (Denham *et al.* 2004).

PEATLAND MANAGEMENT

In general, the subalpine peatlands have not been directly utilised by people, although widespread burning has enlarged grassy mire areas over a long period (Fairbairn *et al*. 2006). The montane peatlands that were formerly used for taro agriculture have declined in importance owing to the relatively recent introduction of dry land crops such as sweet potato. Old ditch systems are still visible in peatlands around the Balim, Mt Hagen and Tari. Limited conversion of these peatlands has occurred, for example small tea plantations near Mt Hagen. Modern agriculture involves drainage and peat subsidence ensues, with up to 3 m of peat altering to a sapric histosol 50 cm in depth. Increased land pressure has led to more cropping of swamp margin and removal of swamp forest where this is accessible. Drainage is often associated with this.

Overall, the montane and subalpine peatlands of New Guinea are not currently threatened by direct utilisation. Destructive fires associated with El Niño events in 1972, 1984 and 1997-8, however, burnt large areas of the peatlands. In most cases this resulted in only minor losses of peat but some peat fires did occur at Kosipe and Mt Giluwe. In a few cases this resulted in the loss of peat soils to mineral horizons. It is unlikely that fire will decrease as there is no effective education program or suppression policy at present.

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