CHAPTER 1

INTRODUCTION

In the past quarter century or so the biogeographers' and ecologists' view of tropical vegetation has undergone considerable transformation. The geologically recent effects of continental drift and the demonstrable influence of Quaternary climatic change and man's activities in tropical regions are now fully accepted. As a consequence, the tropical rainforest can no longer be regarded as a tenuous relic of Tertiary age, subject to disturbance only within historic times, as Richards (1952) postulates:

> 'after existing thus for millions of years, the rain forest ecosystem has very recently - in most of its area only within the last 100 years or so - been rudely disturbed by the spread of western civilization to the tropics... Thus within a very short space of time the primaeval forest communities have been replaced over immense areas by cultivation, ruderal communities and seral stages. Till this change took place the Tropical Rain forest was in a stage of development not unlike the forests of Europe in the Mesolithic period, when habitation was limited to the forest fringes and restricted sites accessible by river. The subsequent destruction of the forest all over the tropics is comparable with the clearing of the European forest by agricultural peoples beginning in the Neolithic period, except that the one process has been accomplished in a few decades, while the other lasted for thousands of years.'

Raven and Axelrod (1972) review the biogeography of Australasia in the light of plate tectonics. The New Guinea highland flora consists predominantly of the more temperate Gondwanic elements, whilst the lowland vegetation is largely of Malesian origin. As a result of the juxtaposition of these diverse groups Raven and Axelrod (1972) suggest that New Guinea 'as a whole is a region of faunal and floral mixing, survival and evolution in the middle to late Tertiary.' These processes presumably continued into the Quaternary, the potential for interaction being modified by climatic fluctuation (Walker, 1972*b*).

The Quaternary era is one of dramatic and widespread climatic change. The effects of the glacial periods, particularly the most recent, have been shown from temperate and from tropical highland regions. It is now becoming clear that, at least in some areas, climatic changes associated with global glaciation had a profound effect on the tropical lowland environment and vegetation also.

The vegetation history of the African tropics is better known than any other tropical area. In particular, it is apparent that the extent of evergreen forest in East Africa was severely restricted during the last glacial (Livingstone, 1975). The region is relatively arid today, and its flora depauperate by comparison with the rest of the equatorial tropics. Richards (1973) attributes the relative lack of floral diversity to the more pronounced effects of climatic change and the longer history of human interference over the African continent.

In contrast to this view, the meagre data that are accumulating suggest climatic fluctuations of at least similar magnitude to have occurred in other tropical areas. Vegetation response to glacial age refrigeration is documented from South America (van der Hammen, 1974) and New Guinea (Bowler *et al.*, 1976, Powell and Hope, 1976).

In common with other tropical areas, the first conclusive evidence of Quaternary climatic change in New Guinea came with the identification of prior glacial landforms. Such features, reviewed by Löffler (1977), occur in both Papua New Guinea and Irian Jaya

(West Irian) on mountains exceeding the Pleistocene snow-line of approximately 3 550 m, almost 1 000 m below that of the present. The most extensive ice cover, perhaps extending as low as 3 200 m, was on Mt. Giluwe in the southern highlands. In the Saruwaged Ranges the snow-line appears slightly higher at 3 650 m to 3 700 m, possibly an artefact of tectonic uplift since the glaciation. A similarly higher snow-line existed in the still ice-capped Carstensz Mountains of Irian Jaya (Hope and Peterson, 1976) perhaps due to relatively lower Pleistocene precipitation in the west of the island.

The severe climatic conditions indicated by the lower snow-line are reflected by changes in the highland vegetation (Bowler *et al.*, 1976). The presence of upper-montane species at only 1 500 m over 30 000 years ago (Powell and Hope, 1976) and 2 550 m at 12 000 BP (Flenley, 1972) implies altitudinal depression of vegetation 'zones' by 500 m to 1 500 m. On Mt. Wilhelm (Hope, 1976*a*) vegetation depression at 2 740 m was at least 700 m until around 10 500 BP, whilst the tree-line was 1 200 m lower than today.

One can only speculate on the ecological effects of these migrations on the montane and lower altitude vegetation. It is likely that, rather than a simple shift in the altitudinal ranges of currently extant vegetation associations, there was considerable individualistic behaviour by plant species. This phenomenon is documented from other areas, both temperate and tropical, e.g. the response of *Podocarpus* on Ruwenzori to changing climatic conditions cited by Livingstone (1975). Extrapolation of the maximum vegetation zonal depression into areas below 1 500 m is untenable, as this would practically eliminate lowland forest and replace it with vegetation of montane affinity. Alternatively, considerable compression of the altitudinal range of mid-montane vegetation must be postulated were the vegetation changes in the highlands to have had no influence in the lowlands.

It is clear that both these hypotheses are too simplistic given the extreme variation in present vegetational patterns in relation to altitude, and the individualistic response of many plants. Whilst the probable effects of the demonstrated depression of higher altitude vegetation on the lowlands undoubtedly lies somewhere along this spectrum, the two extremes, i.e. no influence on lowland vegetation, or complete replacement, can probably be ruled out.

Within the more recent past, human impact on tropical vegetation is now well demonstrated. Diminishing forest cover during the past few millennia is attributed to man's activity both in East Africa (Kendall, 1969) and Central and South America (Bartlett and Barghoorn, 1973, van der Hammen, 1974). In the New Guinea highlands, archaeological evidence indicates complex agriculture perhaps 9000 years ago (Golson, 1977*b*), and forest clearance was widespread by 5000 BP (Powell *et al.*, 1975).

There is thus considerable circumstantial evidence to suggest that the vegetation of the lowland tropics has been exposed to, and may have responded to, changing environmental conditions on time-scales of millions, tens of thousands, and thousands of years. This realisation calls into question the concept of unchanging tropical lowland vegetation. In particular, the prodigious floristic diversity of the tropical rainforest can no longer be attributed to its ancient integrity.

This study attempts to identify and quantify change in the vegetation of a lowland area of Papua New Guinea over the more recent (late Quaternary) extent of this time-scale, and considers the possible determinants of any change.

POLLEN ANALYSIS IN THE TROPICAL LOWLANDS

Although palynology is an established method for reconstructing Quaternary vegetation history in many temperate regions, and has been applied successfully in highland tropical areas, it is almost untested in the lowlands of the equatorial tropics. By contrast with the vegetation of temperate and, to a lesser extent, tropical highland regions, the many species of the low altitude equatorial tropics are supposedly characterised by low pollen production, and entomophilous or zoophilous pollination habit. Faegri (1966) states the pessimistic view that 'pollen analysis is simply not a method for investigating those (tropical forest) vegetational types, unless indirect conclusion can be arrived at from the presence or absence of indicators that do contribute to the pollen rain'.

The floristic diversity of the New Guinea vegetation equals that of other equatorial areas (van Balgooy, 1976), and this vast array of species poses formidable problems for pollen analysis. In addition to the task of identification of sub-fossil grains the large number of taxa involved increases the difficulty of achieving statistically reliable estimates for the values of each taxon. On the other hand, it may be more likely that 'indicator' taxa will be present.

A more fundamental problem remains the characterisation of the vegetation solely on the basis of floristic data. Pollen analytical evidence reveals, at best, only the partial floristic composition of the plant community. Ideally, a reconstruction of the past vegetation may be derived from these data by interpolation from extant communities. Yet, in the tropics, floristic classification of vegetation associations is often not feasible. In Papua New Guinea, recognition of major vegetation formations using the criteria of land-units and physiognomy (e.g. Paijmans, 1975) or physiognomy alone (Webb *et al.*, 1976) may produce more tractable results. As Walker and Guppy (1976) have shown, subjective classifications frequently do not reflect floristic changes. Analyses of lists of tree genera from 78 sites above 1 900 m revealed only one major floristic break, at 2 800 m to 3 000 m. Although altitudinal zonation below this was unsubstantiated by the floristic data, two 'nodes' of generic similarity were recognised: the genus-rich forest of environmentally stable areas, and depauperate derivatives from it.

In view of the paucity of basic ecological and palynological data it seems appropriate that initial palaeoecological research in the lowland equatorial tropics should focus on major changes in the most immediately recognisable vegetation formations. In Papua New Guinea the most striking boundaries in lowland vegetation exist between the forest, and non-forest grassland, 'woodland', or 'savanna' communities.

THE ORIGIN OF NEW GUINEA GRASSLANDS

It is widely argued that, except for swamp and perhaps alpine areas, the present distribution of grasslands in New Guinea is a product of forest clearance and/or burning by man. Lane-Poole (1925), on surveying the forest of the lower Markham Valley near Yalu, hypothesised that

> 'At one time forest of this type stretched all the way along the coast between the mountains inland and the sea, and all along the vast valleys of the Markham and

> Ramu Rivers. Today, artificially formed grasslands have taken the place of the forest on the best of the land, and, in the less fertile areas, a secondary weed growth has established itself.'

Robbins (1963*a*) considers that 'tall' grassland gives way to 'short' grassland under the pressure of continued human interference. Although admitting that the most extensive grassland areas exist under conditions of low, seasonal rainfall and poor soils, he regards environmental factors as secondary to the history of human impact. Robbins sees the pattern of grassland in the Papua New Guinea highlands as reflecting the increasing antiquity of cultivation from west to east. This proposition is amplified (Robbins, 1963*b*) by interpreting the Markham Valley grasslands as lying in the wake of a route of population migration from the coast to the highland interior. 'Only thus', states Robbins, 'can the now largely abandoned Upper Markham grasslands be readily explained.' A similar contention is advanced to account for the extensive grasslands of the Sepik Plains the origin of which Reiner and Robbins (1964) correlate with population movements dated at 500 to 800 years ago by linguistic evidence.

Closer study reveals environmental factors to be of greater importance in the determination of vegetation patterns than Robbins (1963*a,b*) and Reiner and Robbins (1964) consider. Brookfield (1964) emphasises the climatic variation in the highlands in relation to grassland distribution. The Sepik grasslands have been studied by Haantgens *et al.* (1965) who demonstrate considerable edaphic influence on the vegetation. Although agreeing that the grassland is a fire-climax community, these authors regard environmental factors as at least as important in determining the character of the vegetation. Paijmans (1976) suggests that grasslands such as those of the Sepik developed from smaller grassland loci due to the use of fire, particularly in areas of poor soils and seasonal rainfall where the forest was in a precarious balance with the environment.

The survey by Holloway *et al.* (1973) reveals close relationship between the composition of the non-forest vegetation and edaphic and other environmental gradients within the Markham Valley. Eden (1974) finds a general reduction in the extent of grassland and savanna communities in southern Papua with increasing humidity. However the juxtaposition of vegetation types within similar habitats is not entirely explicable by patterns of rainfall, potential evapotranspiration, or the soil moisture availability. Eden (1974) calculates that, at rates of clearance observed today, man's cultivation activities could account for the formation of the whole grassland area within the last 2000 years. However, it is recognised that over a longer period, climatically induced vegetation changes may be of importance.

It is clear, therefore, that sole correlation between the floristic composition of non-forest vegetation and the intensity of human activity is invalid, although this concept continues to surface in the literature (e.g. Seavoy, 1975). Such a correlation can be substantiated only if the effects of all environmental variables are first accounted for. However, the character of many grassland areas is clearly maintained under present day climatic conditions by man's activity, particularly in the use of fire. The contemporary distribution of grassland provides strong circumstantial evidence that man has created, extended, or modified much of the grassland of lowland Papua New Guinea, particularly that in environmentally stressed habitats. However, extrapolation of past vegetation patterns on the basis of present distribution is at best imprecise. Palaeoecological techniques provide the most appropriate, if not the only, means to reveal the history of the vegetation and its environmental determinants.

AIMS OF THIS STUDY

Three basic questions may be posed in relation to the vegetation of lowland Papua New Guinea that might be amenable to solution by palaeoecological research:

(1) Have the present patterns of lowland vegetation, particularly those of the forest and grassland associations, remained stable in the past? If not, what has been the direction and magnitude of any change?

(2) Has Quaternary environmental change, especially the climatic fluctuations demonstrable from many temperate and tropical areas, had any effect on the lowland tropical vegetation?

(3) What is man's role in influencing the vegetation and its current distribution patterns?

This study explores the extent to which palaeoecological methods can answer these problems, and, by corollary, the constraints on the use of such evidence. The central techniques employed are stratigraphic and pollen analysis of lacustrine sediments. Suitable deposits of late Quaternary age are thus required. A robust, independent chronology is essential to allow the reconstruction of the sedimentary history of the site and to provide for the use of time-area based palynological techniques. In a previously unstudied area it is particularly important to distinguish between site-specific events, and those of more widespread significance. Interpretation of stratigraphic and pollen analytical evidence of local habitats is greatly facilitated by an understanding of swamp vegetation ecology. A knowledge of the fundamental aspects of contemporary pollen dispersal is also considered essential in view of the almost total lack of knowledge about such processes in the tropical lowlands. Each of these topics is covered to some extent in this thesis. Emphasis is placed, however, on the application and interpretation of pollen analytical and stratigraphic methods in the palaeoecologically unknown environment of lowland Papua New Guinea.

CHOICE OF STUDY AREA

The vegetation map of Papua New Guinea (Paijmans, 1975) shows many of the more densely inhabited lowland areas to be covered by a mosaic of forest and non-forest vegetation types. However, four major regions may be identified where non-forest vegetation predominates.

Large areas of south-west Papua New Guinea are covered by *Melaleuca* dominated savanna. Extensive areas of grassland with scattered trees of several *Eucalyptus* species occur along the coast of the Central Province, in the region of Port Moresby. These vegetation types are clearly of Australian origin, and are almost restricted in New Guinea to monsoonal areas south of the main dividing range. Their past distribution was probably substantially influenced by the considerable Pleistocene extension of land over the shallow Torres Strait shelf. For these reasons, the development of the vegetation in these savanna areas, whilst of great interest especially in relation to late Quaternary events in tropical Australia (Kershaw, 1975), is unlikely to be representative of lowland New Guinea as a whole.

The Sepik area of north-western Papua New Guinea contains large tracts of grassland. However, many of these are alluvial swamp areas and affected by changing river courses. Sites possessing deposits of suitable antiquity and continuity for palaeoecological research may well exist, but would be hard to locate.

A fourth area, the Markham Valley, has a smaller but well defined area of grassland and other non-forest vegetation. Due to the high relief and sharp environmental gradients, various forest types are also found in close juxtaposition. As with much of the northern coast of New Guinea, the land configuration was little changed during the glacial sea level minimum due to the steep off-shore shelf. The foothills along the margins of the valley contain a number of permanent lakes and swamps of potential antiquity.

Thus, whilst recognising the scientific interest of other lowland areas, this study is devoted to the palaeoecological investigation of sites within the environs of the Markham Valley, Morobe Province, Papua New Guinea.