COMPARATIVE THEORIES OF THE ORIGINS OF AGRICULTURE IN PAPUA NEW GUINEA.

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B. A.

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The work presented in this thesis is to the best of my knowledge and belief, original, except where acknowledged in the text. The material has not been submitted in whole, or in part for a degree at this or any other university.

D. Bensley

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ABSTRACT

This thesis presents an overview of two major theories concerning the origins of agriculture in Papua New Guinea. The theories are a) that Papua New Guinea developed agriculture during the Mid-Holocene (6000-4000 BP), as a result of a transfer of cultigens and agricultural techniques out of Southeast Asia, and b) that agriculture in Papua New Guinea developed as an internal process, independent of outside influences (particularly Southeast Asian), some time in the terminal Pleistocene/ Holocene period (10,000-9000 BP).

The former theory constitutes an early view of the origins of agriculture in Papua New Guinea, and the latter theory represents a more recent view. After testing the two theories against archaeological evidence, it was found that the more recent theory appears to be correct; Papua New Guinea appears to have developed agriculture independently of Southeast Asia, thereby marking it as one of the earliest centres of agriculture in the Southern hemisphere, and possibly the world.
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The origins of agriculture in Papua New Guinea have been a topic of considerable debate. The possibility of Papua New Guinea being an independent centre for early agriculture has previously been overlooked in favour of Southwest Asian and Southeast Asian origins. In recent years, much research has gone into the possibility that Papua New Guinea could have developed agriculture independent of outside influences, in particular influences from Southeast Asia.

The geographical origin of agriculture itself has been a point of reappraisal in recent years. It was originally thought that agriculture arose from a single point of origin, a zone including Anatolia, Iran and Syria. This zone was believed to have given rise to plant domestication some time before 10000-9000 BP, with agriculture supposedly spreading from there to other parts of the world (Hawkes 1969:17; Keightley 1983:21).

Following this early theory, was the belief that agriculture arose in three great regions which were disconnected from each other; China, Southwest Asia, and intertropical America. It has since been shown that most of the major crops known today originated in the tropical or sub-tropical regions of the world (Hawkes 1969:23), and the archaeological evidence of prehistoric agriculture now supports the contention that it has been developed from a fairly large number of places instead of just diffusing from one, or a small number of hearths of discovery (Cohen 1977:24; Bellwood 1985:207). Independent origins in many different parts of the world are now considered probable and these centres are no longer confined to the northern hemisphere (Hawkes 1969:23). The origins of agriculture in Southwest Asia and Europe have traditionally been
seen as prompted by an advance in knowledge, population growth and/or climatic change (Hawkes 1969:23; Layton et.al. 1991:261), while other possible independent centres of agriculture have often been overlooked or dismissed.

**AIM**

In recent years, interest has developed in the origins of agriculture within Papua New Guinea. Two major theories have emerged concerning the origins of agriculture in Papua New Guinea; an early view, and a more recent one. The first view was that Papua New Guinea only developed agriculture after a transfer of cultigens and agricultural techniques out of Southeast Asia some time in the Mid-Holocene. The more recent theory claims that agriculture in Papua New Guinea had a local origin, independent of Southeast Asia, which developed in the terminal Pleistocene / Holocene period.

The aim of this thesis is to present and assess these two theories. I aim to test whether archaeological data show that the more recent theory can replace or entirely discount the earlier view. The major questions then are, whether and when agriculture diffused from Southeast Asia into Papua New Guinea, and whether or when agriculture was developed as an internal process within Papua New Guinea itself. The concept that Papua New Guinea had a local origin for agriculture has often been overlooked, as the time frame was seen as too early for the accepted time-depth for agriculture in Southeast Asia. If it can be shown that Papua New Guinea did develop agriculture at the end of the Pleistocene or in the early Holocene, then it would present a new possibility for an independent centre of agriculture in the southern Hemisphere.
BACKGROUND INFORMATION

The oldest known archaeological material in Papua New Guinea so far comes from an occupation site on the Huon Peninsula, where a series of large flaked blades, or waisted axes (see Figure 1), have been dated by thermoluminescence to 40,000 years BP (Mountain 1991:54).

![Figure 1. Waisted axe from the Huon Peninsula, Papua New Guinea. (Groube 1989:296).](image)

The earliest archaeological evidence for human occupation in the Highlands of Papua New Guinea comes from two sites; Kosipe, an open site at 2000m above sea level (asl), and Nombe, a rockshelter at 1660m asl (Haberle 1993:120). Both of these sites have been dated to around 26,000 BP.

Formerly, it was a comfortable hypothesis that Papua New Guinea, isolated from Australia by rising sea levels at 12000-8000 BP, received its major
tuberous (taro and yam) agriculture from the waves of Austronesian-speaking settlers in their tropical course towards the more remote islands of the Pacific, beginning around 6000 BP (Yen 1973:82; Yen 1985:318). It is this theory that has now been strongly questioned by a number of scholars: Jack Golson, Doug Yen, Jocelyn Powell and Matthew Spriggs, to name just a few.

The evidence for the initial stages of environmental management or manipulation, cultivation, and domestication, all play an important role in the question of when Papua New Guinea first developed agriculture, as these were all vital stages in the transitions to agriculture. Cultivation in the sense of the small-scale manipulation of a few edible plant species may significantly have predated agriculture, in the sense of economic dependence on cultivated plants (Yen 1973:63; Cohen 1977:26). The archaeological evidence now appears to indicate that the knowledge of cultivation techniques is universal, or at least that such knowledge is significantly more widespread in time and space than the actual practice of agriculture as a subsistence strategy (Cohen 1977:26; Powell 1982:225). It has also been pointed out (Powell 1982:225) that cultivation techniques may first have been applied to plants whose value was medicinal, magical, or utilitarian, rather than primarily dietary. If this is so, then it would imply that agricultural techniques were known and widely used long before they were utilised for food supply (Cohen 1977:26). This could be true for any place seen so far as a centre for early agriculture, including Papua New Guinea, and therefore it could prove very difficult to show which areas or countries actually developed agriculture first.

Environmental management was one of the first stages in the manipulation of plants in the transition towards domestication. It can be difficult to ascertain just when people first began to manipulate their environments, and what practices actually constituted environmental management. The first tasks of environmental manipulation may even have been unintentional. Groube
(1989:299) believes that in Papua New Guinea the first tasks of environmental manipulation may have included increasing the area of disturbance by opening up canopies to sunlight and encouraging the plants sought for food. Other initial stages of exploitation may have included trimming, ring-barking, and tree-felling with the aid of fire.

In order to document all the evidence of human interference with the environment, I will be looking at the very beginnings of plant exploitation and manipulation, right through to the established agricultural systems of today. There have been debates about which of the domestication or cultivation processes came first. For the purpose of this thesis I intend to see cultivation as preceding domestication. Cultivation is seen as wild-plant food production involving transplanting, weeding and perhaps drainage and irrigation (Spriggs 1993:137). Cultivation represents significantly greater energy inputs in systematic clearing of the land and tilling of the soil, along with the planting of crops (Spriggs 1993:137). Zhimin (1989:645), sees cultivation as bestowing labour on or tillage of the land in order to improve the growth of plants. It has been suggested that the earliest cultivations in Papua New Guinea could have been the local domestication of native plants such as nut and fruit trees like Pandanus (Bulmer 1977:69). Crop domestication has been defined as the alteration of the reproductive system of a plant population by sustained human intervention, so much so, that the domesticated forms become dependent on human assistance for their survival (Spriggs 1993:137). Agriculture encompasses both cultivation and domestication, but cannot singly be seen as the cultivation of plants; it also includes systems which encompass animal production, concepts and methods of tillage, and relationships to the natural environment (Yen 1973:68). Yen (1982:293), also believes that domestication was a form of genetic-environmental manipulation that continued through prehistory as an alternative mode of intensification.
THEORIES IN QUESTION

THEORY NUMBER ONE:

A number of archaeological sites associated with the domestication of plants in Papua New Guinea span the mid-Holocene (6000-3000 BP), prompting suggestions that humans were interfering with their environment and experimenting with agricultural techniques, around this time (see Table 1). This theory states that the earliest agricultural developments in Papua New Guinea were adopted only after certain cultigens and agricultural techniques were transferred out of Southeast Asia in the Mid-Holocene (Brown 1978:3; Yen 1982:282; Kelly 1988:159). Some of the subscribers to this early theory believe that there was no plant cultivation practised in Papua New Guinea prior to the wave of introduced Southeast Asian cultigens; that technology in the form of stone tool complexes came first, followed by the later introduction of agriculture, and the domestication of pigs, some time in the Mid-Holocene (Brown 1978:3).

The major proponents of this early theory are mostly social anthropologists such as P. Brown (1978), D. Feil (1987) and R.C. Kelly (1988).
<table>
<thead>
<tr>
<th>Site</th>
<th>Present vegetation</th>
<th>Altitude asl</th>
<th>Age BP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draepi-Mijnjigina</td>
<td>Lower montane forest</td>
<td>1890 m</td>
<td>2300</td>
</tr>
<tr>
<td>Tugeri</td>
<td>Lower montane forest</td>
<td>2450 m</td>
<td>2500</td>
</tr>
<tr>
<td>Kamapuk</td>
<td>Lower montane forest</td>
<td>2050 m</td>
<td>4500</td>
</tr>
<tr>
<td>Sirunki</td>
<td>Lower montane forest</td>
<td>2550 m</td>
<td>4500</td>
</tr>
<tr>
<td>Manton</td>
<td>Lower montane forest</td>
<td>1590 m</td>
<td>5000</td>
</tr>
<tr>
<td>Yeni Swamp</td>
<td>Savanna and Lowland rain-forest</td>
<td>320 m</td>
<td>5000</td>
</tr>
<tr>
<td>Mugumamp Ridge</td>
<td>Lower montane forest</td>
<td>1600 m</td>
<td>6000</td>
</tr>
</tbody>
</table>

Table 1. Some archaeological sites associated with agriculture in Papua New Guinea supporting Theory One, according to (a) present vegetation type and (b) altitude. (Haberle 1993:111).
THEORY NUMBER TWO:

The more recent theory regarding the origins of agriculture in Papua New Guinea claims that the Sahul continent was settled by hunter-gatherers around 40-30,000 BP, and an endogenous succession or evolution to agriculture took place in the northern part, before the arrival of the Austronesians at around 6000 BP (Yen 1982:291). It has been suggested that given the time scale of Papua New Guinea’s human occupation (approximately 40,000 years), Papua New Guinea could have been a centre of plant domestication, independent of and prior to any plant introductions from Southeast Asia (Golson 1977:46; Foley 1986:275). It has been suggested that the time-depth of human occupation in Papua New Guinea, coupled with the range of indigenous food crops and those used for other purposes, suggest that plant domestication could have occurred and indigenous agriculture developed, early and independent of any external introductions (Powell 1982a:28; Bellwood 1985:206). Given that the early theory called for the diffusion of plants and agricultural techniques out of Southeast Asia around the Mid-Holocene, this second theory claims that the concepts of plant domestication and cultivation had already been employed in Papua New Guinea to some extent, prior to any possible Southeast Asian introductions. This theory also claims that if any Southeast Asian cultigens were introduced, then they would have just reinforced any earlier horticultural experiments within Papua New Guinea (Powell 1982b:211). Given the plant resources endemic to Papua New Guinea, and the fact that a number of them are currently cultivated (for example: sago, *Australimusa* bananas, sugarcane and some green vegetables), it has been argued that it was likely that some form of horticulture may have been present in Papua New Guinea at an early date. The known time-depth of humans in Papua New Guinea could allow for the occurrence of endemic plant domestication, independent of external introductions (Christensen 1975:33).
This theory calls for the Late Pleistocene or Early Holocene domestication of certain plants in Papua New Guinea's Highlands. The evidence from one site, the Kuk swamp near Mt. Hagen, has led to generalisations about the entire agricultural history of Papua New Guinea. There could be evidence for the first attempts at plant domestication and swamp cultivation, starting at c.9000 BP, and followed by at least five phases of agricultural development in that part of the Highlands (Gillieson et.al 1985:32, Bayliss-Smith & Golson 1992a:1). Although it is still not known exactly which plants were grown in these 9000 BP gardens, it has been suggested that taro was the likely candidate (Allen 1970:182; Spriggs 1982a:315; Golson 1989:682; Swadling & Hope 1992:27). So far there has been a distinct lack of remains of the appropriate plants to confirm this suggestion. The major proponents of this theory are Golson (1976;1977;1981;1982;1985;1989;1990;1991), Bayliss-Smith (1992), S. Bulmer (1977;1982), Powell (1970;1976;1977;1980;1982), Spriggs (1982;1993) and Yen (1973;1982;1985;1990). Some of these proponents believe that the origins of some plant species (taro and yams) being Southeast Asian, does not necessarily prove that Papua New Guinea's agricultural origins were dependent on Southeast Asian plants.

Yen (1982:291) believes that a suite of plants were domesticated in Papua New Guinea that included basic staples, vegetable and fruit species that were able to sustain human populations as they settled in diverse and foreign ecologies. Yen also believed that this occurred from the beginnings of hunting and gathering and was a continuing process, despite the fact that this continuity may have been interrupted by further colonists out of Southeast Asia, as claimed for the early theory.

The analysis of this theory will focus on the physical evidence of the swamp gardens at Kuk, and the artefacts associated with the swamp; along with the archaeological evidence from other nearby sites, such as Wanlek.
RESEARCH STRATEGY

Through reassessment and re-analysis of the existing literature I aim to test these theories by discounting either one or both, if the evidence demands. The thesis will examine factors that could have led to agriculture in both time frames, such as changes in environmental conditions, demographic, cultural and social factors.

The bulk of evidence for agriculture in Papua New Guinea so far comes from the Highlands sites of Kuk, Manton, Wañlek, Sirunki, Draepi-Minjigina and Chuave. (see Figure 2.) Investigations of the major plant species in question will also be undertaken, to compare the evidence from Southeast Asia with that from Papua New Guinea. The majority of the information on the domestication of plants and animals will come from the accumulation of data from detailed taphonomic, cytological, palynological and archaeological studies, provided by the literature.

The following chapter will focus on the environmental conditions in Southeast Asia and Papua New Guinea, from the late Pleistocene through to the mid-Holocene. By reconstructing palaeo-environments we can hypothesise how pre-agricultural societies subsisted. The impact that agriculture and other human interferences had on the environment in Southeast Asia and Papua New Guinea can be very useful for determining when certain archaeological events occurred. The early signs of human intervention may provide some clue as to why people made the transition to agriculture, and I will be comparing the various other theories behind the transition to agriculture in both regions. The origins of agriculture in Southeast Asia, along with the origins of certain plant species, will also be documented in Chapter Two.

Chapter Three will focus on the two theories in greater detail, providing all the evidence for the agricultural origins in Papua New Guinea, from a number of archaeological sites. The evidence for Southeast Asian plants in
Papua New Guinea's prehistory will also be documented. Also in this chapter will be a section on the debate over the introduction of pigs into Papua New Guinea, and their role in the development of agriculture, along with evidence of linguistic links between Southeast Asia and Papua New Guinea. The outcomes or results of agriculture in Papua New Guinea will also be included in this chapter, such as the environmental, social or cultural changes relating to agriculture; for example population changes, or the establishment of trade routes or exchange relations.
Figure 2. Location of pre-agricultural and major post-agricultural sites in Papua New Guinea. (Swadling and Hope 1992:16).
CHAPTER TWO

PALAEO-ENVIRONMENTAL CONDITIONS IN SOUTHEAST ASIA.

Due to the fact that one of the major theories concerning the origins of agriculture in Papua New Guinea involves the Southeast Asian region, I will be comparing the palaeo-environmental conditions in Southeast Asia, with those of Papua New Guinea, in order to gauge whether there was a direct link between both regions, in conditions that led to agriculture.

Hominids belonging to the species of *Homo erectus* have been found in Indonesia (Java), and appear to span a long period of time prior to 500,000 BP (Reynolds 1993:12). However, in keeping with the supposed time frame of human presence in Papua New Guinea (40,000 years, the oldest human remains of modern type in Southeast Asia have been found at Ngandong (Java), and Niah Cave (Sarawak). The fossils at both Ngandong and Niah Cave date to around 40,000 BP, and are considered to be anatomically modern (Bellwood 1985:49-50; Reynolds 1993:12).

I am primarily concerned with the environmental conditions from the Late Pleistocene to the Mid-Holocene (c.11000 to c.4000 BP) in Southeast Asia (including China), and Papua New Guinea, as this was the time frame most important to the origins of agriculture in the Southeast Asia-Pacific region. However, some background information on the environmental conditions from c.40,000 BP may provide some insight into pre-agricultural subsistence, and hence lead to the reasons behind the transition to agriculture.

Beginning with Southeast Asia, it is generally believed that there was a temperate latitude cold phase around 35,000 BP in Southeast Asia, with a following interstadial that peaked somewhere between 30,000 and 25,000 years
ago. After 25,000 BP the temperatures in the region started to drop again to their lowest point at about 18,000 BP. Climates and sea-levels settled at approximate present conditions by around 8000 BP (Bellwood 1985:33). Much of Southeast Asia would have been exposed as dry land by low sea-levels for long periods during the Pleistocene, especially at the peak of the last glaciation around 18000 BP. This is indicated by the drowned river channels and sediments in the beds of the South China and the Java Seas (Bellwood 1985:7). During much of the Pleistocene both Sundaland (Southeast Asia) and Sahulland (Papua New Guinea and northern Australia), would have been above sea-level as large continental areas, and periods of drowning like the present probably only occurred for short periods (Bellwood 1985:33; Swadling & Hope 1992:26). The period of continentality at the maximum of the last glacial would certainly have produced drier climates. Lower temperatures would have reduced convectional rainfall, and winds would likely have been drier, as they would have crossed larger land areas and cooler seas. High latitude glaciation would have caused an increased pressure gradient between the Asian and Australian continents and the equator; dry seasons would have become longer, and the equatorial regions would have experienced briefer and smaller rainfall maxima. The average rainfall in Sundaland could possibly have been reduced by as much as 30% during the last glaciation (Bellwood 1985:34).

There was a warming interval between 14000 and 4000 BP in Southeast Asia and China. This ameliorating trend generally resulted in a moister environment with thicker vegetation becoming dominant over much of the region. Temperatures also rose and water distribution from periglacial and marine transgressive sources increased. This resulted in diminished natural barriers on land, submergence of many land bridges in the sea, and a greater abundance and an increasingly greater diversity of faunal and floral resources (K.C.Chang 1978:3). The rapid post-Pleistocene rise in sea-level led to a rapid
and very great loss of land, due to the particularly flat nature of the terrain. The former coasts and river valleys of Thailand, Vietnam, and Cambodia became a drowned landscape, and evidence for coastal settlement between about 10000 and 6000 BP has been covered (Higham & Maloney 1989:654). All of these changes saw a very different environment in Southeast Asia, in the period immediately prior to the development of agriculture.

THE ORIGINS OF AGRICULTURE IN SOUTHEAST ASIA

The question of when societies associated with agriculture first appeared in East and Southeast Asia has also become a subject of considerable debate. Until quite recently the prevailing view was that the complex of traits which included the domestication of plants and animals, and the manufacture of pottery, originated in China and slowly filtered down into Southeast Asia (Keyes 1977:15; K.C. Chang 1986:71). The emergence of agriculture in Southeast Asia was thought to have begun no earlier than 3500 BP or considerably later than the time at which social groups based on agriculture are known to have first arisen in China, approximately 8000-7000 years BP (Keyes 1977:15). Archaeological evidence from Southeast Asia has now shown that there was just as much experimentation with cultivation happening in the southern regions of Asia, as there was in the more northern regions, like China. Archaeological advances have now supposedly pushed the beginning of agriculture in China very close to the beginning of the Holocene (K.C. Chang 1986:71).

The north Chinese early agriculture emphasised cereals (Setaria and Pannicum millets), whereas in Southeast Asia, roots and tubers and other vegetatively reproduced plants dominated. It is now also reasonable to assume that rice was one of the earliest plants to be cultivated or domesticated by food gatherers in both tropical and north, warm temperate regions, where standing
water or intermittent flooding prevailed during the growing season (T.T.Chang 1989:408).

K.C.Chang (1986:71) believes that diverse and plentiful environmental resources were a prerequisite for the transformation of hunters-fishers-gatherers into the early cultivators and animal herders, as these environments were suitable for providing the necessary experiments towards domestication. These experiments may have included the encouragement of certain species of plants in favour of others, or the cultivation of small areas of plants near settlements. In China, the relation between woodland and grassland played a crucial role in the initiation of agriculture, as neither environment separately provided a conducive setting for the beginnings of agriculture (Keightley 1983:23). It is believed that the right kinds of plants for this early cultivation (for example: cereals), are found in the open grassland environments, although the grasslands themselves were not the home of food-gathering peoples. It was at the boundary between woodland and grassland, in an intermediate savanna environment that cultivation supposedly first began in China. While agriculture was incipient, people may have lived in this intermediate zone for prolonged periods, finding both natural plants and animal resources in the transitional environment (Keightley 1983:23; K.C.Chang 1986:71).

In China there are indications of a Mesolithic economy predating and helping set the stage for the development or adoption of agriculture. The Upper Pleistocene exploitation patterns geared towards the hunting of large fauna and a variety of smaller game, seem to have given way to a variety of regional economies directed toward the use of coastal and riverine resources and the processing of vegetable foods. This pattern both preceded and accompanied the early spread of farming in China (Cohen 1977:153; Keightley 1983:23).

There are a number of prevailing views on just how old the first agriculture in China is. It had been suggested that the first Chinese agriculture
occurred among peoples of the Yangshao tradition, which has been dated to 7000-6000 BP (Zhimin 1991:195). However, the discovery of the Peiligang tradition in Henan Province was hailed as a breakthrough in studies of the early Neolithic in north China, as its radiocarbon date of 8000-6000 BP, confirmed that at around 8000 BP at the earliest, foxtail millet began to be widely cultivated (Zhimin 1991:195).

Rice is one species that plays a major role in the early agriculture of East and Southeast Asia. It is now a generally accepted theory that the Asian cultigen of rice evolved from an annual progenitor over a broad belt that extended from the southern foothills of the Himalayas across Upper Burma, northern Thailand and Laos, to northern Vietnam and into southwest and southern China (Bellwood 1985:208; T.T.Chang 1989:409). The wild annual ancestor of modern cultivated rice (Oryza nivara), was first domesticated somewhere in the above zone. Rice (Oryza sativa) in the form of charred grains and husks has been found in more than 30 sites in the Yangtze Valley and along the Southeast coast of China. Bellwood (1985:208), states that the Lower Yangtze archaeological sites are early enough in date (early Holocene, or 9000-8000 BP), to suggest that they could represent a localised and independent centre of rice domestication. It is possible that rice domestication in this area developed from a sedentary lifestyle based on the harvesting of wild annual rice developed at the beginning of the Holocene. Harvesting could then have transformed into systematic cultivation as a response to some kind of stress, such as climatic changes or population pressure on the land.

The South China belt was originally covered by dense, temperate forests, but millennia of cultivation and human habitation have completely altered the state of the lower slopes and plains. Keightley (1983:39) believes that this is one part of China where conditions were favourable to the prehistoric inhabitants for their initiation of plant manipulation and domestication. The wide distribution of
wild rice in southern China indicates that the middle and lower reaches of the Yangtze River must have been one of the centres of origin of cultivated rice (Zhimin 1989:645). It is believed that initially rice grains were gathered and consumed by prehistoric people of the humid tropics and subtropics where the self-propagating plants grew on poorly drained sites. It has also been suggested that the domestication process progressed from grain gathering to human cultivation and onto domestication (Bellwood 1985:208; Zhimin 1991:195).

In Southeast Asia, archaeological research in the valleys of the Red, Chao Phraya and Mekong rivers of Thailand, shows that there appeared to be a major cultural change around 5000 BP, which involved the occupation of the tributary valleys by small groups of permanent settlers (Higham and Maloney 1989:650). The earliest settlements of this expansion are at Phung Nguyen, and a at number of sites in Northeast Thailand, most notably those of Non Nok Tha, Ban Chiang, Ban Phak Top, and Nan Kao Noi. These sites best document this initial expansionary phase of human settlement onto the Khorat Plateau. Analysis of human and organic remains at these sites show the inhabitants were wide-ranging in their subsistence activities. The remains of rice have often been recovered, either as grains or as tempering in pottery (Higham & Maloney 1989:650). Excavations at the site of Non Nok Tha have shown that efforts to exploit wild plants and animals opened the way first to minor efforts at horticulture and then to full-scale agriculture and animal husbandry. This site was also rich in pottery which bore the imprints of cereal grains and husks, which were identified as Oryza sativa (rice). The findings at Non Nok Tha concluded that rice was an established cereal in mainland Southeast Asia by as early as 7000 BP. Implements typically associated with rice cultivation and processing have also been recovered at Non Nok Tha, and they appear much earlier and may indicate that rice agriculture dates as far back as 9000 BP in this
region. If this is the case then this region would predate the cultivation of rice in China by at least a millennium (Higham & Maloney 1989:662).

The site of Kok Phanom Di stands on marine clays laid down during a series of high sea-levels between c.7000-4000 BP. It has been suggested that rice was propagated in this area by 6000 BP (Higham and Maloney 1989:662). The settlement of Kok Phanom Di (c.4000 BP) involved forest clearance and rice consumption. The evidence from the 1985 excavation at Kok Phanom Di indicates that both plants and animals were domesticated and radiocarbon dates from the pollen cores suggest that human modification of the vegetation occurred from c.8000 BP (Higham & Maloney 1989:662).

It is believed that there are two strategies for agriculture in Southeast Asia, opposed in principle, and which are both dependent on the characteristics of the humid tropical ecosystems (Glover 1977:156). The first is the practice of shifting or swidden agriculture, which is epitomised by diverse assemblages of crops and animals being raised in structural and functional interdependence, mirroring the complex structure of the natural ecosystem. The second is the monocultural, intensive, fixed field agriculture which is typified by wet rice cultivation in Southeast Asia (Harris 1969:6). Southeast Asia is now seen as an area of origin of many cultivated plants, whereas it was previously seen as a combination of diffusion and invasion from China.

Southeast Asian agriculture has emphasised vegetatively reproduced root crops, especially yams, taro, bananas, and tree fruits, and these are now generally believed to have been cultivated much earlier than the cereals (K.C. Chang 1978:9). Taro and yams were presumably developed or introduced into the area by at least 6000 BP, or possibly earlier, but so far there is little evidence to show an earlier date (K.C. Chang 1978:9). The taro (Colocasia) poses a difficult origin problem since it grows freely in a wild or feral state along river banks in many parts of Southeast Asia and India, and its homeland
remains unknown (Bellwood 1985:236; Golson 1990a:48). Taro is one of the root crops that are presumed to predate rice, as part of the ancient horticultural base of the region (Bayliss-Smith and Golson 1992a:16). There is little archaeological evidence on the Southeast Asian mainland that throws light on the antiquity of root-crop and tree-crop agriculture.

Taro is a very important plant in terms of its antiquity in Southeast Asia and also in Papua New Guinea. The origin of taro relates directly to the major questions of this thesis; whether agriculture developed independently in Papua New Guinea in the terminal Pleistocene/Holocene period or later, or whether it developed as a result of diffusion from Southeast Asia, either in the Mid-Holocene or earlier. Taro (Colocasia) has previously been seen as Southeast Asian in origin, and the taro that has undergone cultivation in Papua New Guinea was also previously assumed to be of Southeast Asian origin. The fact that taro has been proposed as the crop cultivated in wetland gardens at the Kuk archaeological site in the Papua New Guinea Highlands and dated to 9000 BP, raises the question of how taro came to Papua New Guinea before it appears in the archaeological record of Southeast Asia. The evidence from the Kuk site forms the major part of Chapter Three, and will be discussed in detail there.

It is not certain whether taro (Colocasia) is among the species that were domesticated in Papua New Guinea, or whether it arrived through diffusion, perhaps with the main yam species Dioscorea alata and D. esculenta. These according to Yen, are definitely of Southeast Asian origin (Bayliss-Smith and Golson 1992a:16). Nowhere in the archaeological record of Southeast Asia has taro been found to the extent to which it has in the Wahgi Valley of the Papua New Guinea Highlands. If this is the case, then it can be asked why was rice not involved in the transfer out of Southeast Asia, instead of taro? Perhaps the environmental conditions in Southeast Asia were not as suitable as they were in Papua New Guinea, at the beginning of the Holocene, and so taro did not
become as important as other cultigens, such as rice. Rice as a crop in pondfields in the Philippines and some Indonesian areas is a late development postdating the presumed dispersal of Oceanic speakers about 5000 BP (Spriggs 1982a:317).

It terms of the origins of agriculture in Southeast Asia, it appears that the long-held belief that agriculture originated in China and filtered down into Southeast Asia and onto Oceania is now untrue. The archaeological evidence in Southeast Asia has indicated that agriculture developed independently in a number of areas. The archaeological dates for the origins of agriculture in Southeast Asia are certainly comparable with those of China and in some places are even older. It is now seen that rice cultivation had a southern Asiatic origin, although it appears to have been experimented with in many regions before becoming domesticated.

PALAEO-ENVIRONMENTAL CONDITIONS IN PAPUA NEW GUINEA

As noted, humans have possibly been in Papua New Guinea for 50,000 years, but have more definitely been dated to 40,000 years BP (Golson 1977:46; Yen 1982:291; Mountain 1991:54). It is currently thought that the period from 32000-28000 BP in Papua New Guinea was one of forest advance, indicating warmer and more settled conditions, but the majority of the first 20000 years of this period were dominated by cold conditions, with glaciers on the highest peaks. The most extreme climate was experienced between 20000 and 15000 BP (Golson 1982:299), with 2000 sq.km of glaciers covering the highest mountain peaks between 17000 and 14000 BP, with surrounding areas of alpine and subalpine grasses and shrub vegetation (Bulmer 1982:173). After the coldest period, the treeline descended to around 2200m until c.14000 BP (Golson 1982:299; Swadling and Hope 1992:26), and the final major glacial retreat
began during the period of 15000-14000 BP and continued until around 9000 BP.

As in Southeast Asia during the last glacial maximum (18000 BP), climatic conditions in Papua New Guinea were cooler and drier, as there was an increase in aridity. Open sclerophyllous forest (eucalypt) may have been present in many of the larger valleys, such as the Markham, Ramu and Lower Sepik. Rainforest was not as extensive at this time as it was to become later, as changes connected with the cooler climates and lowered sea-levels (resulting from glacial advance), caused a retreat of rainforest in favour of more open vegetation in some areas of the lowlands. This resulted in large areas of coastal plains being covered in grasslands and savanna, and forests being compressed downhill at lower altitudes. Forests were replaced with alpine grassland over vast areas of upland, above a lowered treeline at 2000-2400m. The sea level was approximately 150 m below its present level at the maximum low (Golson 1981a:34; Bulmer 1982:173).

The Highlands were definitely cooler and possibly more cloudy throughout the last glacial period, as shown by *Nothofagus* forests which were much more widespread than in the early Holocene. The climate in the Highlands was some 5-6 degrees cooler than present day temperatures, which resulted in a general depression and compression of the vegetation belts (Loffler 1977:4). As mentioned above, the retreat of the snowline commenced before 15000 BP, and it had cleared all but the highest summits by 11000 BP. Forests started to invade the mountains, passing 2900m at around 13000 BP and had reached their present limits by 9000 BP. Climates similar to present are indicated soon after 10500 BP by the enrichment of subalpine forests by lower altitude trees (Loffler 1977:5; Powell 1977:17; Golson 1991:86; Swadling and Hope 1992:26). Three enlarged mountain habitats were formed at around 11000 BP, with the marked increase in rainfall and mountain forest cover. These were the high mountain temperate
forest, the mid-mountain subtropical forest, and the low mountain tropical forest. Swampland and tropical rainforest expanded over areas previously occupied by the open forests and savanna, and at higher altitudes the treeline moved upwards to 4000 m, with the subalpine grasslands being replaced by mixed montane and beech forests. Palynological research has shown that beech was widespread in late Pleistocene montane forests between 1500 m and 2100 m, indicating a constant cloud cover and mist. The decline of beech at a number of palynological sites at the time of the temperature rise across the Pleistocene / Holocene boundary heralds general changes in forest composition towards more mixed taxa, with fewer tree ferns and lianas, and more palms, small trees and oaks (Golson 1991:86; Swadling and Hope 1992:26). The increase of oak forests can be interpreted in two ways. They may suggest that milder or drier climatic conditions prevailed, or they can also be associated with anthropogenic influences. For example, an increase in oak in the pollen diagrams from Mt. Wilhelm at 6500 BP could be seen as indicating human impact on the vegetation there, by clearance for cultivation (Powell 1977:18).

The early Holocene period of warmer, wetter conditions took place around 9000-8000 BP and continued until 5000 BP. The upper treeline, about 200 m higher than present, is thought to indicate this warmer, wetter climate. After the most extreme climate was experienced between 20,000 and 15000 BP, the temperatures rose, bringing a complex suite of changes, including the freeing of the main highland valleys from their prevalent cloud and mist and the consequent diversification of the regional forest. Climates similar to present had become established in regional areas by 9500 BP, as mentioned above. The land bridge to Australia was flooded some time between 8000 and 5500 BP and is thought to have affected prevailing wind and rainfall patterns. The final period of the modern climate began about 5000 BP, with generally cooler and more fluctuating conditions. Ice readvanced in the western mountains, and a lowering
of the upper treeline and changes from grassland to tundra conditions on the
summit of Mt.Wilhelm are thought to be evidence of a slightly deteriorating
climate period (Bulmer 1982:174; Swadling and Hope 1992:26).

It was the early Holocene period of warmer, wetter conditions that are
thought to have been the most favourable for the transition to agriculture in
Papua New Guinea, although the mid-Holocene conditions were also relatively
fair, in regards to the development of agriculture. If relying on palaeo-
environmental evidence alone, this fact makes it difficult to isolate just when
agriculture may have begun.

PRE-AGRICULTURAL SUBSISTENCE IN PAPUA NEW GUINEA

This section will examine the potential resource base available to support
the pre-agricultural populations. Although it is the period from the Late
Pleistocene through to the Mid-Holocene that is of direct relevance to the
question of the origins of agriculture in Papua New Guinea, there is evidence of
human interference with the environment from c.30,000 BP in Papua New
Guinea which helped to set the stage for the development of agriculture.

It is a reasonable inference from the archaeological record that the human
settlement of Papua New Guinea began before agriculture of any kind was
established in the island. The early communities are believed to have lived off
the wild resources of the land (Golson 1981a:36). Groube (1989:293), believes
that the first human penetration into Papua New Guinea came from tropical
forested southern Asia, by people that were already physically and culturally
adapted to humid-forest conditions. In the late Pleistocene, the coastal forests of
Sahulland must have reached full maturity at various times, as climatic shifts
during the Pleistocene, fluctuating cloud cover, and associated temperature
changes would have ensured the vegetation was not uniformly mature. Stone
axes which are believed to have been used for forest clearance, have been found at Kosipe, dating to 26,000 BP, and pollen cores from an adjoining swamp show evidence of forest disturbance and charcoal, dated to 30,000 BP. It is believed that humans were successfully penetrating and modifying the inland forests of Papua New Guinea during the late Pleistocene, as seen by the relatively large tools suitable for the clearance of forests or at least manipulation (Groube 1989:295).

Several environments were available to the first humans on their arrival in Papua New Guinea. In montane Papua New Guinea there were two alternatives; the forested mountain slopes and basins, and the higher ecotone made up of the treeline and the subalpine grasslands. It has been suggested that the lower montane forest would have offered richer possibilities than higher areas, to the pre-agricultural people of Papua New Guinea and this is the environment that the majority of archaeological sites are found in (Hope & Hope 1976:39). The montane forest most likely offered many edible and otherwise useful plant species, to the early inhabitants of Papua New Guinea. The ameliorating post-glacial climate not only enriched the highlands as a habitat for humans, but it also established an environment suitable for plant husbandry, previously only developed under more benign conditions at lower altitudes (Golson 1991:88).

It has been hypothesised that human activity played an important role in environmental development within Papua New Guinea from initial dates in the range 40,000-28,000 BP (Groube 1989:295). Early humans would probably have been capable of sea crossings amongst the island archipelagos to the north and east of the mainland of the Pleistocene continent of Sahul (Mountain 1991:55). It has been suggested that the coast and inland regions of northern Sahulland would have offered a far richer and more diverse resource base than even the closest of the islands (Mountain 1991:56). The first humans to arrive along the northern coasts of Papua New Guinea would certainly have
encountered full tropical lowland rainforest with high humidity and high non-seasonal rainfall inland from the coastal mangrove and sago swamps (Mountain 1991:58).

Two major hypotheses exist concerning the nature of early Highland occupation. Hope and Hope (1976:39) suggest that early occupations may have been concentrated along the ecotone made up of the treeline and subalpine grasslands within the altitudinal range of 1800 to 2500 m. It has also been suggested (Bulmer 1977:68), that while early hunter-gatherers may have exploited the resources up to above 3500 m, settlement would have mainly been focused below 2000 m.

Evidence from the highlands of mainland Papua New Guinea strongly suggests that humans were altering the landscape in small areas as early as c.30,000 BP, as mentioned previously (Groube 1989:295). The evidence includes individual events in which the pollen diagrams reveal a local change from tree to grass pollen accompanied by a sudden increase in charcoal, indicating a local firing event followed by forest regrowth. Excavations at Nombe rockshelter have produced a late Pleistocene edge-ground axe, showing deep striations at right-angles to the cutting edge, which has been interpreted as being utilised for cutting substantial branches or felling small trees (Mountain 1991:64). Highland Papua New Guinea was covered in rainforest in the late Pleistocene and some evidence for the exploitation of the forest resources comes from Yuku rockshelter where Pandanus nuts were present in layers dated to 12,000 BP or earlier (Bulmer 1977:66).

The original settlement of the mountains of Papua New Guinea was more than likely by hunter-collector groups in the glacial period, extending their range of resources to include the mountain forest and/or moving into the inter-montane valleys to specialise in the use of resources in the mid-to-upper mountain zones (Bulmer 1977:68). These hunter-gatherers probably relied on the wide range of
ecological zones because of the uncertainty of access routes, and the seasonal availability of plants and game (Powell 1977:17). The natural processes of environmental change at the end of the glaciation and in the early post-glacial times were important in changing the size and distribution of different vegetation zones and introducing a new major environmental force; the clearing of forest for cultivation (Bulmer 1977:68). During the colder glacial climate between 33,000 - 9000 BP the mountain forest zones moved to lower warmer altitudes. The mid-mountain forest zones were possibly the most attractive to the hunter-gatherers, with its comfortable subtropical climate, open oak forests, abundant animal life and edible plants, nuts and fruits (Bulmer 1977:68).

Hope and Hope (1976:39) have suggested that early hunter-gatherers used the zone of high alpine grassland for hunting and communication until climate change caused it to decline in area as forest was able to thrive at higher altitudes. It has been suggested that there would have been no great scarcity of food resources in the lowland rainforests, and that a broad spectrum subsistence system could have evolved in the higher altitudes. The importance of fruit and nut species as nutritionally superior to edible roots, palm products and green vegetables has been emphasised as they may have formed the staple foods of the early inhabitants in Papua New Guinea, and been one of the first group of plants to be tended and transported into groves and later garden sites (Mountain 1991:59). Conversely, it has also been suggested that hunter-gatherers may not have been able to fully support themselves within a tropical rainforest, as it has been shown in ethnography that most hunter-gatherers exist in reciprocal relationships with food producers outside the forest areas. Also, it has been shown that many plants that are staples for hunter-gatherers (like nuts and tubers), do not grow abundantly in primary tropical rainforest. Although tropical rainforests are one of the most productive terrestrial ecosystems, faunal and plant foods suitable for human consumption are neither abundant nor easily
accessible. Many potential food plants like tubers, nuts and fruit grow more efficiently at the edge of forests and in areas of disturbance where the light is greater than in high-canopy, light-reduced, primary-forest (Bulmer 1977:68; Mountain 1991:57).

Following the last glacial maximum at around 18000 BP, there is a small but gradual increase in the number of known archaeological sites in the Highlands and in the density of archaeological debris within these sites. This may suggest that the human population of the Highlands was beginning to increase towards the end of the Pleistocene period, and that subsistence activities must have also increased during the period following the last glacial maximum (Mountain 1993:123). The end of the glacial period brought a warmer, wetter climate, and the tropical rainforest expanded over the lowland plains and foothills. When the treeline climbed and the subalpine grasslands were reduced in area between c.10,500 and 8000 BP, people may have increased their dependence on forest resources (Christensen 1975:31). The period from about 8500 to the present is characterised by some minor climatic changes and by the onset of human impact on the land and the widespread reduction of forest by humans (Loffler 1977:5).

By the end of the Pleistocene, hunting techniques and forest management strategies must have been adapting to climatic change. Humans would have been adapting their forest management practices to more intensive use of the plant products through increased clearance and more active encouragement of foods like tubers and fruit (Mountain 1991:64). *Pandanus* could have been the primary resource of forest-based populations after 10,500 BP (Christensen 1975:31). The horticultural component of the earliest subsistence patterns would likely have had very little effect on the natural vegetation, and would probably have been below the horizon of archaeological and palynological visibility as it would have
been concentrated on naturally open areas, near swamps or along watercourses (Christensen 1975:33).

It is around the time of the Late Pleistocene (11,000-10,000 BP), that the first human use of a number of rockshelters is noticeable; for example, Kafiavana at 1350 m in the Eastern Highlands Province, Kiowa at 1530 m in Simbu Province close to Nombe, and the Manim site at 1770 m off the Wahgi Valley.

**TRANSITIONS TO AGRICULTURE IN PAPUA NEW GUINEA**

Mountain (1991:54), believes that there seems to be no reason why *Homo sapiens* hunter-gatherers of the Late Pleistocene should not or could not have been as effective in environmental management on a small scale like their later descendants. Hayden (1990:35) agrees, stating that "the archaeological record speaks of no cultivation or herding in the face of major or minor climatic fluctuation, resource stresses of all imaginable magnitudes and durations, occurring in all possible environments for two million years. Why should any such perturbations result in food production in the last 10000 years?". Hayden believes that humans could have been experimenting with agriculture prior to the documented evidence. The reasons behind the emergence of agriculture in many parts of the world are extremely varied. This section examines the various reasons behind the transitions to agriculture by hunter-gatherer groups in Papua New Guinea.

The majority of opinions support the belief that the origins of agriculture are a reaction to stress, due to either direct demographic pressures on resources, or to less specific environmental and social factors affecting resource availability. It is now commonly believed that hunters and gatherers will not turn to cultivation, which requires higher inputs of labour and forward planning for
land clearance, weeding, harvesting and irrigation, unless they are forced to do so by a growing imbalance between population size and/or social demands, and available foods (Bellwood 1985:207). Yen (1983:80), supports this belief and states that the human population level of an area may be regarded as the primary incentive to technological development or adoption of greater intensity in production methods.

In Papua New Guinea, it is assumed that a simple system of slash-and-burn cultivation was the first attempt at agriculture. Boserup (1965:28), also sees a relationship between population growth and agrarian change. The process of the conversion to grasslands is seen as the deflection of the natural vegetation succession under a system of simple shifting cultivation, where, in conditions of slow, natural regrowth, expansion of population led to a shortening of the fallow. This is one possibility that may have occurred in Papua New Guinea, as the grasslands of Papua New Guinea today are extremely widespread. The conversion to grassland makes the techniques of shifting cultivation inadequate for its cultivation and requires then an input by humans in the form of tillage with or without fertilisation, to secure output. Boserup (in Golson 1976:204), believes that this is how intensive agricultural practices emerged from within a system of simple shifting cultivation. She believes that the change from one fallow system to another is usually part of a more complex pattern of change involving also a change of factor proportions and a change of tools and methods. The transition to more intensive systems of land use takes place in response to the increase of population within a given area (Boserup 1965:28).

In opposition to this, it has been suggested that the theoretical framework in which the transition from hunting and gathering to herding or cultivation is conceived as an evolutionary (Boserup) progression from one distinct type of society to another, should be displaced in favour of a theory that explores the usefulness of treating hunting and gathering, herding, and cultivation as
alternative strategies which are singly or in combination, appropriate to particular social or natural environments (Layton et al. 1991:255). A number of factors have been identified which may render a shift from hunter-gathering to intensive husbandry adaptive. They include climatic change, technological innovations, the elaboration of social networks, and the appearance of new varieties of animal or plant amenable to intensive husbandry (through local mutation or by diffusion). The relative plant and animal biomass may influence whether animal or plant husbandry offers the best return, and it has been suggested that population growth alone cannot be accountable for the shift away from hunting and gathering (Layton et al. 1991:262).

Prior to this belief it was suggested that the development of a pattern of interchange of resources between groups exploiting contrasting environments was the single most important factor in establishing an agricultural economy (White 1971:183). This may have occurred to some extent in the Papua New Guinea Highlands. It is commonly believed that although population growth in Papua New Guinea may have contributed to the intensification of agriculture, it was not likely to have been the sole cause.

An earlier opinion of Golson (in Feil 1987:25) was that a chain reaction of events resulted, which irreversibly led to agriculture and hence, pig domestication in Papua New Guinea. Feral pigs apparently lost their foraging areas of wild foods, and humans increasingly lost their hunting habitats and became more reliant on domestic sources of proteins. Because of this, taro production became more intensive, to take up the slack of degraded environments on dry land increasingly marked by grasslands. Also, pigs became domesticated and more dependent on agricultural production and human care. Kelly (1988:159) claims that the development of agriculture may also have been prompted by efforts to compensate for the unfavourable energetics of small game hunting.
It has been suggested that the disturbance associated with the earliest phases of agriculture would not alter the natural regeneration pattern of the forest, and therefore it would be very difficult to separate these changes from the natural successional patterns which follow climatic change.

Mountain (1991:61) believes that there is a body of both environmental and archaeological evidence that provides the basis for a hypothesis suggesting that Late Pleistocene people in the Highlands of Papua New Guinea were capable of altering the density and distribution of edible resources long before true domestication or large-scale clearance of forest. Haberle (1993:109), also believes that plant manipulation, by clearing and burning was an important part of Highland Pleistocene human subsistence. It has been suggested that the late Pleistocene populations were smaller and less dense than in subsequent times and that there was less impact on the environment than during the Holocene. This is evidence that the early inhabitants of the Highlands were actively manipulating the environment, rather than just playing a passive role. The earliest stages of forest clearance may have involved the extension of existing grasslands or herbaceous swamps to enhance the growth of plants such as *Pandanus*. Haberle (1993:113) focuses on a site in the Southern Highlands where wetland subsistence systems are currently operational. This site is known as Haeapugua, where pollen analysis from a core site took place. The site has been dammed by a Pleistocene lava flow allowing volcanic ash, and organic and lacustrine sediments to accumulate in the basin throughout the Pleistocene. Through Carbon-14 dating it has been shown that continuous sedimentation extends back beyond 30,000 BP. The basal laminated clays of lacustrine origin are overtopped by a shallow-water swamp sequence, with wood remains towards the top suggesting that the swamp was forested at different times (Haberle 1993:114). The pollen data shows major changes (around 21,000 BP), in the composition of the surrounding vegetation such as the decline of
Nothofagus, Castanopsis and Elaeocarpus from before 30,000 BP to the present, possibly in response to developments within the catchment (Haberle 1993:116). Also around 21,000 BP, grassland begins to be established near the site. These grasslands dominate at around 17,000 BP, indicating the gradual establishment of extensive grasslands around the site at the expense of forest cover until ca. 8,000 BP. Records of fire history are available from a number of sites within the Highlands, and they show that fire was a major factor in the formation of grasslands during the last 30,000 years. At Mt. Jaya, burning was apparent by 13,500 BP, showing that people entered cold, mountainous regions during the Pleistocene. At Kosipe (SE Papua New Guinea), forest clearance seems to have been maintained from at least 24,000 BP until 10,000 BP, when the site was apparently abandoned (Haberle 1993:117).

Haberle (1993:109) believes that the archaeological appearance of agriculture at Kuk in the Wahgi Valley, immediately after the Holocene warm conditions were established, has presented three possibilities: i) that similar activities were developed earlier at lower altitudes and brought to the Highlands when conditions were suitable; ii) that the Highlands population had developed agricultural techniques and adopted crops from the immediate forest during the late Pleistocene, but that these are not visible in the archaeological record; or iii) that the results at Kuk represent the true beginnings of agriculture in the Highlands.

The evidence of forest interference in the Late Pleistocene resulting in the exploitation of the Kuk swamp in the Wahgi Valley, indicates that the forest inhabitants of northern Sahulland had developed strategies of survival in the forest which involved alteration of the existing vegetation. Groube (1989:299) believes that the systematic removal of rainforest would never have been undertaken without necessity, as it would be such a formidable task. Manipulation of the forests to enhance and improve stocks of existing plant
foods offers a more plausible explanation for the scale of intervention. Groube believes that the giant swamp-taro was likely to have been present in Papua New Guinea, at river and swamp margins at the time of the first human arrival. Groube (1989:295) hypothesised that forest management gradually turned to forest gardening over more than 30,000 years. He gives a hypothetical model of the transformation from forest foraging to gardening. Forest hunting or foraging was the initial exploitation of the new forest resources; both animal and plant. The second stage in this model is food-plant promotion, which is the selection of desirable plants and their promotion through minimal clearance and/or expansion of the forest fringes. This stage is more environmental manipulation than strict food-plant manipulation. The last stage is that of forest management with permanent or semi-permanent promoted stands of some plants. This strategy could persist for thousands of years without change and depending on rainfall, it could prove very stable.

As previously mentioned, hunting techniques and forest management strategies must have been adapting to climatic change, by the end of the Pleistocene. Environmental change after the glacial maximum of about 18000 BP indicates the rapid demise of much of the subalpine zone, as the increased temperatures allowed forest growth to occur at higher altitudes. Humans would most likely have been adapting their forest management practices to more intense use of the plant products through increased clearance and more active encouragement of foods like tubers and fruits (Mountain 1991:64). Hope (1983:42) states that there is no sharp dividing line between exploitation of wild resources, management of them, planting and care of selected species or domesticated horticulture or silviculture (the cultivation of forest trees). It has also been suggested that only when the need for fencing or ditching of gardens became increased did large-scale forest clearance and agricultural techniques become detectable in the archaeological record. The period of modern climate
from about 5000 BP to the present is seen as one of complexity and diversification of human culture, in a period of deteriorating climate and adaptation to new and various ecological change (Bulmer 1982:202).

**DOMESTICATED PLANTS IN PAPUA NEW GUINEA**

It has been a long-held belief that many of the dominant species of plants under cultivation in Papua New Guinea, were of Southeast Asian origin. Although this is in fact true, it was presumed that agriculture in Papua New Guinea did not become a major force until after a transfer of these exotic crops and cultivation techniques out of Southeast Asia, and not a lot of credit was placed on Papua New Guinea to have been a centre of independent domestications.

In this section I will be focussing on the main species of plants that were seen to have been domesticated within Papua New Guinea, and the domesticated plants that were believed to have been introduced from elsewhere, to determine whether a case can be made for the independent origins of agriculture in Papua New Guinea. In the following chapter, I will focus on the archaeological sites that support or reject the theory that Papua New Guinea can be seen as an independent centre of agriculture.

The basic notion has been that tuberous plants, and fruit and nut trees, together with their vegetative reproduction (which are characteristic of Papua New Guinea and the Pacific Islands today), formed the basis of an original agriculture in Southeast Asia, which was subsequently replaced by systems based on the cereal rice. It was this basic notion that suggested that the agriculture found in Papua New Guinea and the Pacific Islands was actually derived from Southeast Asia; the people who carried it eastward doing so before rice became dominant in Southeast Asia (Golson 1989:678). This was originally
thought to have been no later than the Mid-Holocene, but recent archaeological work in Southeast Asia has shown that the domestication of rice occurred in a number of places around the Early Holocene, as mentioned in the first section of this chapter. If tuberous plants, and fruit and nut trees are assumed to have predated rice in Southeast Asia, then they could date to the Late Pleistocene or the very Early Holocene. The exact time of entry for the Southeast Asian crops thought to have been introduced into Papua New Guinea is still unknown, yet it is generally considered to have been prior to 4500 BP (the original date considered for the transfer of rice out of South China), but it must be earlier, as taro has been identified in Papua New Guinea at 8500 BP at Lake Wanum (Powell 1982a:28; Powell 1982b:211; Golson 1985:308).

It has not been unequivocally demonstrated, but three genera of ethnographically important food crops are assumed to have come to Papua New Guinea, at an early but as yet undetermined date. These include taro \((Colocasia esculenta)\), two species of yams \((Dioscorea alata\) and \(D. esculenta)\), and bananas \((Musa\) species of the Eumusa section) (Wilson 1985:90). Some of the secondary crops are of foreign, mainly Asian origin also, like the beans \(Psophocarpus tetragonalobus\) and \(Dolichos lablab\). The diffusion of Southeast Asian plants into Oceania underwent a succession of adaptive and inventive agricultural steps from a hypothesised base of an early root-crop agriculture (Yen 1973:84). Once again, taro features prominently in this section as it is one of the most widespread cultigens in Papua New Guinea, whether it was introduced or indigenous. The staples of most regions in Papua New Guinea today are the exotic crops mentioned above, most of which have originated in areas to the north and north west. Although the sweet potato is presently the most dominant of cultigens in Papua New Guinea, its introduction was much later than the other species of plants (Powell 1982a:28) and therefore it does not feature strongly in this thesis. As mentioned in the Southeast Asian section of
this chapter, the taro (*Colocasia*) poses a difficult origin problem, as it is seen as growing freely in a wild or feral state along river banks in many parts of Southeast Asia and India, and its homeland remains unknown (Bellwood 1985:236; Golson 1989:682). Questions have been raised as to the origin of the *Colocasia* taro, which has often been proposed for the early wetland gardens at Kuk archaeological site in the Wahgi valley of Papua New Guinea. Taro is found in both wild and cultivated forms from as far afield as India right across Southeast Asia, to Papua New Guinea and Australia. The results of chromosome studies raise the possibility of two separate domestica tions: one in Southeast Asia and one in Papua New Guinea (Golson 1990a:48).

Matthews (1991:69), believes that the cultivated varieties of taro must have originated within the natural geographical range of the species, if *Colocasia esculenta* originated somewhere as a natural species and the geographical range was not extended by humans before its cultivation. Observation of other *Colocasia* species and of wild taro suggests the possibility of a natural range extending from northeast India across to Papua New Guinea and Australia. If taro was this widespread before it became cultivated, then the present cultivated varieties may have diverse and independent origins (Matthews 1991:69). The natural range of taro (*Colocasia esculenta*), may have included northern Australia, Papua New Guinea and the Solomon Islands and domesticated forms may have derived from wild-type *C. esculenta var. aqualitis* (Spriggs 1982b:8; Spriggs 1993:138). This variety has been recorded as producing very little starch and it has been suggested that other properties such as the edibility of the shoots and leaves and medicinal uses may have led to its initial cultivation, with selection for starch content occurring under cultivation and at an earlier date than originally thought (Spriggs 1993:138). This fact could prove very difficult to determine, particularly the time at which humans ceased utilising taro for medicinal reasons, before they began to cultivate it for dietary
reasons.

The indigenous Melanesian agricultures have been characterised as dominated by the field cultivation of *Dioscorea* yams and *Colocasia* taro. Staple root crops, vegetatively reproduced, show biological characters in common, but physiological adaptations that contrast, such as wet and dry seasons (Yen 1982:283). In Melanesia today, it is rare that one crop is present in total absence of the other. Systems in "wet" ecologies (riverine, swamp, stream), tend to exhibit dominance of taro, but often there is a "dry" component in which some yam will be cultivated. In tropical rainforests taro may dominate the "dry" or swidden gardens (with the absence of water control techniques), while yams can be adapted by elaboration of agronomy to the "wet" conditions (Yen 1982:283). Yen believes that the species of taro present in Papua New Guinea, *Colocasia esculenta*, is represented by three chromosome-number forms only in India, along with other forms of taro (*Alocasia* and *Amorphophallus*), yet this does not determine its origin. On the mainland of Southeast Asia today, the *Colocasia* is found in cultivation, but wild forms are rare or absent, while the narrow range of plant variation does not indicate proximity to a centre of origin. Another taro species is *Cyrtosperma chamissonis*, adapted as a staple in the eastern Melanesian islands. Wild species of this are found in Papua New Guinea, but the Pacific cultivated species has a narrower distribution, indicating that it is the first example of what could be an endemic cultigen, and may be a regional domesticate from within the Papua New Guinea-Fiji confines (Yen 1982:284). If *Colocasia* taro is indigenous to Papua New Guinea, then the ultimate origins of the Oceanic wetland systems that are based on taro, may lie in dryland systems for the manipulation of wild plant populations in the lowland rainforests (Bayliss-Smith and Golson 1992a:16). It has been difficult to distinguish between plants ultimately derived from cultivated introductions and those of natural occurrence, when trying to identify naturally occurring taro. Matthews
(1991:75), believes that the geographical origin of taro is somewhere within northeast India or Southeast Asia. The diversity of the eastern tropical aroid flora (the botanical family of *Colocasia*) tails off eastwards very sharply at Papua New Guinea. The natural range of taro may extend as far as Papua New Guinea, or slightly further east, and there is possibly a northern most limit within the temperate region of China.

The belief that the Pacific agricultural complex had its origins in Southeast Asia has come under reassessment in recent years (Yen 1991:48), and I will now present some of the evidence that could support the theory that Papua New Guinea was in fact an independent centre of agriculture within the Southeast Asia-Pacific region. This evidence is in the form of various species of plants that are believed to have been internally domesticated within Papua New Guinea. Yen (1982:282) believes that it is only in recent years that the issue of domestication of plants has been separated out from the origins of agriculture. He also believes that genetic selection, including domestication, is an agricultural intensification that has been a feature of Oceania, continuing into the recent past. The process of domestication can be seen as a more intensive system of plant exploitation or manipulation than the cultivation of plants, and in Papua New Guinea there is now evidence that suggests that some species of plants may have undergone the domestication process, prior to the introduction of Southeast Asian cultigens. Papua New Guinea is very rich in plants that are of great use to humans and has been settled sufficiently long enough to have been a centre of agriculture, independent of anything that was happening in Southeast Asia.

A number of crop plants in Papua New Guinea are now considered to have been domesticated in the area from indigenous wild stock. These plant species include bananas of the *Australimusa* branch, some minor species of yams, oil and nut *Pandanus* trees of various species providing fruits and nuts rich in proteins and fats, the cane grass *Setaria palmifolia*, a number of edible
grasses and green vegetables, providing minerals and vitamins, and sugarcane (*Saccharum officinarum*) (Powell 1977:18; R. Bulmer 1982:62; Powell 1982a:28; Golson 1985:309; Yen 1985:319; Golson 1989:681). Botanical research has indicated that *Australimusa* bananas and sugarcane (*Saccharum officinarum*), two important elements of the complex, were likely to have been of Papua New Guinean origin, and it was this that aided in raising the possibility of independent origins for agriculture in Papua New Guinea. It is believed that indigenous plants were taken into domestication in Papua New Guinea over virtually the whole environmental range met within the Pacific and included the suite of produce mentioned above, comprising starch foods, vegetables and fruit and nuts with the potential to sustain broadly based agricultural economies (Golson 1991:48; Yen 1985:319). The suite of plants that were domesticated in Papua New Guinea were able to sustain the human populations in their settlement of diverse and foreign ecologies from the beginnings of hunting and gathering, and this was believed to have been a continuing process through to present communities (Yen 1982:291).

In the lowlands it is possible that by the time the Southeast Asian yams, taro, and bananas were transferred to Papua New Guinea, some form of subsistence agriculture based on local semi-domesticated and domesticated species was being practised. The establishment of taro, yams and bananas in rainforest communities by 8000 BP, would have been relatively simple, particularly if some form of subsistence agriculture was already being practised. Between 8000 and 5000 BP the warmer and wetter climate would have favoured the expansion of the tropical tuber crops, the bananas, and the sugarcane into the highland areas (Powell 1977:18).

Agricultural systems based on tubers and tree fruits may have developed independently in Papua New Guinea by about c.9000 BP, judging by the evidence of a tradition that relates to swamp drainage at Kuk, in the Wahgi
Valley (Bellwood 1985:241). It is now assumed that the widespread gardens for which these drains existed were for taro cultivation. The evidence of swamp drainage at Kuk makes up the greater part of the following chapter, so I will not endeavour to explain it here. Identification of taro pollen has also been claimed for the Lake Wanum region of the Markham Valley, at a date of c. 8500 BP (Spriggs 1982b:7). In Highland Papua New Guinea, it has proven extremely difficult to distinguish taro pollen from that of other genera, as the claimed fossil taro pollen are not closely matched to the reference collections (Spriggs 1982b:7). Taro is naturally a plant of wet and even swampy areas in the Indo-Pacific region. The pollen sequence from Lake Wanum in the Markham Valley, indicates that anthropogenic disturbance of the vegetation occurred between 8500 and 7850 BP, as there were increased values for woody non-forest pollen taxa and an influx of carbonised fragments. Spriggs (1982b:8) suggests that this, and the Kuk evidence together provide a possibility of an independent domestication.

Plants indigenous to Papua New Guinea could have provided an adequate agricultural base, over the introduced plants from Southeast Asia. The origins of some plant species (taro, yams etc), being Southeast Asian does not conclusively prove that Papua New Guinea’s agricultural origins were dependent on Southeast Asian plants. The extent to which plants indigenous to the island are cultivated in gardens in Papua New Guinea presently makes it reasonable to assume that agriculture could have begun in Papua New Guinea independently of Southeast Asia (Golson 1981a:34). The starchy foods (yams, bananas, sago), could have been the staples, and the leafy green vegetable could have provided the minerals and vitamins. Pandanus trees would have supplied proteins and fats and sugar cane likely provided energy sources. A small number of these indigenous plants are true domesticates, known only in their cultivated form (Golson 1981a:36).
If *Colocasia* taro is of Southeast Asian origin, then this information still does not explain the anomaly of taro appearing in the archaeological record in Papua New Guinea around the Early Holocene, but not in Southeast Asia at a similar time. Perhaps environmental conditions in Southeast Asia were better suited to the cultivation of rice, rather than taro. The size and growth of the human populations in Southeast Asia may also have been a prominent factor that determined which cultigens were grown. There is no real evidence to show that taro originated in either Southeast Asia or Papua New Guinea, but it does not rule out the possibility of Papua New Guinea being an independent centre for early agriculture (Bellwood 1985:236). Plant remains are not commonly preserved on archaeological sites and the few recorded species available do not often span 5000 years, which could be one reason why it was originally thought that agriculture only began around this time. The following chapter documents the major archaeological sites that juxtapose data to the two opposing theories: that agriculture in Papua New Guinea was the result of diffusion from Southeast Asia, and secondly that Papua New Guinea developed agriculture independent of outside influences.
CHAPTER THREE

This chapter focuses on the two theories set out in Chapter One, in greater detail. Prior to the extensive archaeological research undertaken in the Papua New Guinea Highlands, the choices that were available for development sequences, appeared to be i) that plant domestication was the consequence of the introduction of Southeast Asian cultigens, particularly yam, taro and the *Eumusa* bananas, or ii) the domestication of plants in Papua New Guinea began independently of the Southeast Asian centre, as an incipient horticultural phase (Yen 1973:75).

EVIDENCE FOR THEORY ONE

The Austronesians

It was originally thought that agriculture in Papua New Guinea arose when an agricultural expansion out of Southeast Asia occurred with the Austronesians, around the Mid-Holocene (6000-4000 BP). In the first section of this chapter I will show why this could have been the case, as many of the archaeological, agricultural sites in Papua New Guinea support this, by dating to around the Mid-Holocene (Yen 1985:319). This belief was also aided by the fact that a number of species of plants that have been domesticated in Papua New Guinea (taro, yams and *Eumusa* bananas), are of Southeast Asian origin. Some of the earlier opinions on the origins of agriculture in Papua New Guinea will be presented, before looking at some of the evidence that could support this early theory.

This early theory claims that taro, which is perhaps the most important of the cultigens introduced into Papua New Guinea in regards to the origins of agriculture, came into the Pacific with Austronesian speakers at c. 6000 BP. This
presents an obvious discrepancy with the evidence from Chapter Two, where
taro pollen has been identified at Lake Wanum in the Markham Valley, dating to
8500 BP. The evidence from the Kuk site in the Wahgi Valley also disputes this
claim, where the presence of taro has been assumed at 9000 BP, but this will be
discussed in the following section (Yen 1982:292). The expansion of the
Austronesians within the past 5000 years is believed to have been closely related
to their economic development and Bellwood (1976:153), claimed that the
settlement of most of the vast area of Oceania began soon after the time that the
first definite evidence appears for developing plant and animal domestication in
Southeast Asia. It has now been shown that agriculture arose in a number of
places in Southeast Asia around the terminal Pleistocene / Holocene period,
therefore this claim of people moving into Oceania with the advent of
agriculture at around 5000 BP, is no longer true.

Of all the language families in Papua New Guinea, the Austronesian
family is the only one which is clearly immigrant, having come from Southeast
Asia in the last 5000 years (Foley 1986:280). Presently there are about 200
Austronesian languages spoken in the Papua New Guinea area, many in close
proximity to the Papuan languages. The present Austronesian languages can be
traced linguistically to a proto-language (Proto-Austronesian), perhaps as a
chain of related dialects that developed around 5000 BP. Linguistic observation
has shown that words for taro, yam, bread-fruit, banana and coconut (but not
rice), are all present in the Proto-Austronesian vocabulary. This made it highly
likely that these plants were present in Papua New Guinea by 5000 BP, and
possibly in domesticated forms (Bellwood 1976:153; Foley 1986:280). As
mentioned above, it has since been shown that these species have likely been in
Papua New Guinea for approximately 9000 years. The yams (*Dioscorea* spp.),
of which there are five main species in Oceania, were probably first brought
into cultivation in the areas of seasonal monsoon rainfall in northern Southeast
Asia. The most important species of Aroids is taro (*Colocasia esculenta*), and it
is grown throughout Oceania and may have originated as a cultigen in equatorial Indonesia, although its exact origin is still unknown, as mentioned in the preceding chapter. The cultivation systems of the Austronesians (c.5000 BP) ranged from the most simple forms of swidden gardening to intensive monocropping of irrigated fields, and these gardening forms have been identified at a number of sites in the Papua New Guinea Highlands. Along with the introduction of agriculture, it has also been claimed that the Austronesians brought with them to Papua New Guinea a number of other innovations and introductions such as pottery, and domesticated animals like pigs, fowl and dogs (Foley 1986:280). A number of Papuan languages today have words for "pig", which are closely related in form to the Austronesian word for "domesticated pig", "*mporo". The intrusive Austronesian population may have possessed technological superiority over the indigenous Papuan groups in a number of areas, which suggests that borrowing from the prestige population in both language and culture would most likely have occurred (Foley 1986:281). It was originally thought that the pig, dog, and fowl did not appear to have any wild ancestors in the greater part of Austronesia, and therefore whenever and wherever they are found in archaeological deposits beyond their wild habitats, it was assumed that humans were involved (Bellwood 1976:162). Previously the earliest report of pigs were from 6000-5000 BP, and were presumably associated with agriculture. The argument was that since the pig is not a native animal to Papua New Guinea, then it was hardly likely to have made its way across the water barriers of Eastern Indonesia. Instead, it was believed that the pig came into Papua New Guinea as a husbanded animal, and since there is now such a connection between pigs and agriculture in Papua New Guinean and Oceanic systems, its appearance implies the simultaneous arrival of Southeast Asian cultivated plants (Golson 1982:298). Apart from the identification of two pig incisors at two separate rockshelters in the Highlands of Papua New Guinea, that date to the Early Holocene, the first non-indigenous animals (pigs),
appeared in two shelter sites at about 6000-5000 BP; a date that correlates well with the introduction of pigs in Timor. It is possible that pigs at this date in the Highlands may have been feral relatives of lowland animals, being hunted or captured and reared in settlements to be used later (White 1971:190). It is generally assumed that the presence of pigs in Papua New Guinea does imply that agriculture was present in the island or nearby.

The argument surrounding the introduction of pigs into Papua New Guinea will be discussed in greater detail in the following section.

Other Reasons for Agriculture in Papua New Guinea

Some of the subscribers to the early theory believed that it was unlikely that plant cultivation was practised in Papua New Guinea prior to the wave of introduced Southeast Asian cultigens; that technology in the form of stone tool complexes came first, followed by the later introduction of agriculture, and the domestication of pigs (Brown 1978:3). These introductions supposedly reached the Highland peoples by ancient trade routes into the interior (Brown 1978:3). The ground stone axe or adze which became the basic and characteristic tool for clearance and building, appears in the archaeological record around 5000-6000 BP. Stone tools at this time consisted of flaked stone artefacts, waisted blades, scrapers, edge-ground artefacts and ground stone axe-adzes. These tools are believed to have been used for forest clearing, house building, fence building and to fashion wooden implements (Brown 1978:24). Forest clearing for shifting cultivation occurred some 6000 to 5000 years ago, when agriculture and pig domestication were supposedly first practised, according to Brown (19:24:78). The Mid-Holocene age for these tools shows that humans were actively experimenting with agricultural techniques around this time. Grasslands were created by burning and clearing for gardens, hunting, and defence, and cultivated food replaced wild foods as the mainstay of the diet. The main food crops were again presumably taro and yam, introduced from Southeast Asia.
Pollen analysis from early sites in the Wahgi Valley suggests that shifting agriculture was practised over 5000 years ago. At a later date of 3000-2000 BP, the swamplands were extensively drained with ditches for intensive cultivation, while fence posts and wooden spades were also utilised. Brown (1978:24) also believed that because swamp gardening is supposedly more complex and advanced than shifting cultivation, such an intensive technique implies the existence of a large and stable population and stable communities with houses. The widespread systematic water control and swamp drainage gardening in the Wahgi valley associated with specialised techniques using spades, is believed to have been used for taro cultivation. Other crops such as bananas, yams, sugarcane and beans were likely grown on the hill slopes. It is possible that the valley population increased to require more permanent forms of agriculture, and the moist valley bottom beds were adapted to the requirements of growing taro. The slopes were not continuously occupied and the population shifted to the slopes at different times (Brown 1978:25).

Much of this early research acquired these Mid-Holocene dates prior to the extensive research undertaken at the Kuk agricultural site (which has since been dated to 9000 BP at the earliest), and therefore they obviously support the theory that agriculture only developed in Papua New Guinea in the Mid-Holocene (6000-4000 BP).

**Sites of Forest Disturbance and Reduction**

It was also originally thought that agriculture may have only begun in the Mid-Holocene in Papua New Guinea, because a number of archaeological sites with agricultural features have been dated to around the Mid-Holocene (6000-4000 BP). This is due to the fact that it is not until the Mid-Holocene that clear indications of anthropogenic clearance and burning activities are shown in pollen diagrams, suggesting that humans were experimenting with agricultural techniques at this time (Haberle 1993:109). The anthropogenic clearance of
forests in Papua New Guinea does not necessarily mean that agriculture arose only after a transfer of cultigens and techniques out of Southeast Asia. It could just mean that Papua New Guinea started to develop agriculture independently of Southeast Asia at this time. This is one theory that I have not explored in this thesis so far, as it has never really been proposed as an hypothesis.

Palynological studies in Papua New Guinea have indicated that the reduction of forest attributable to human influence, occurred firstly just prior to 5300-5000 BP, with further clearances at 4000 BP, between 2200 and 2000 BP, between 1400 and 1200 BP and lastly, between 400 and 300 BP, at a number of sites. Where fire has been used for clearing sites for gardening or for hunting, the rate of change has rapidly increased. Evidence from pollen analytical studies suggests that forests were cleared and grassland developed from at least 5000 BP in the Mt. Hagen area. The grasslands have been easily maintained over the years by the continuing use of fire, and valley-bottom swamps have been created as the result of accumulated sediments following accelerated soil erosion on slopes cleared of vegetation (Powell 1980:127). Some of the swamps in the Mt. Hagen area have provided the best archaeological sites, such as Kuk. The creation of the swamps was followed by recovery and stabilisation of the forests for some 2400-1800 years in most areas (Powell 1982b:216; Golson 1982:301). By 4000 BP considerable areas of forest had been cleared throughout the Highlands; gardens had been expanded into high altitude areas and the swamplands as well as mountain slopes were being used systematically for agricultural purposes. A system of shifting agriculture with long-term fallowing was unlikely at this time as gardens were more likely of the mixed-crop type with both indigenous domesticates (bananas, sugarcane, Setaria, Rungia, Saccharum edule) and exotic species (taro, yams and gourds), being grown (Powell 1982b:224). By 2000 BP further pressure had been exerted on the forests throughout the Western Highlands and grasslands were expanding. Gardening of these areas had become possible with the development of
techniques of complete tillage. By 1200-1000 BP a system of controlled tree-fallowing had become established in the Wahgi valley and also in the Chimbu valley, and more intensive use of the dry land sector was then possible (Powell 1982b:225).

There are a number of major archaeological sites and a few smaller sites that have contributed data about the history of agriculture in the Highlands. The major sites are in or around the Mt. Hagen district, and they include Manton, Wañleq, Kuk, and Draepi-Minjigina (see Figure 3). Of these four, Kuk and Wanleq have provided the oldest dates, and will be discussed in greater detail in the next section of this chapter, as they concern the second theory. The other sites mostly date to around the Mid-Holocene, and it is these that are believed to support the theory that agriculture came from Southeast Asia.

The site of Manton, is a few kilometres from the major archaeological site of Kuk on the southern side of the Wahgi Valley, near Mt. Hagen and lies at 1590 m above sea level. Manton site was the first open agricultural site investigated, but the only possible food plant remains found were from Lagenaria (in the gourd stage of growth, not the edible stage), dated to around 2500 BP (Bulmer 1982:196). The stratigraphy at this site indicated that there was a zone of disturbed sediments lying between the basal sand and an undisturbed upper peat. Within this zone a series of ditches, cut from three different levels were found together with artefacts, such as wooden stakes, pointed digging sticks and paddle-shaped spades, along with stone axe-blades, sharpening stones, cooking stones, and charcoal. The ditches were seen as drainage channels dug to control water movement during episodes of gardening on the swampland. Radiocarbon dates indicate that the Manton site ranges from 5000-4800 years in age, and two of the ditching systems have been dated to 2300 BP and 980 BP (Bulmer 1982:196; Powell 1982b:216). Pollen diagrams now begin to provide a continuous record of the regional vegetation history. They show that considerable inroads had been made into the forest by clearance
by around 5000 BP. The pollen diagrams also register a fairly rapid recovery of forest in relation to woody non-forest from a low point about 4000 BP. A stable relationship between forest and non-forest vegetation was not recorded until about 1000 BP at this site (Bulmer 1982:196; Christensen 1975:33).

Draepi-Minjigina is a site that consists of a sinuous swamp at 1890 m above sea level, in the hilly country at the base of Mt. Hagen. Pollen diagrams have shown that inroads had also been made into the forest by clearance around 5000 BP, not unlike that of Manton. Charcoal has been identified from a cooking pit embedded in coarse organic detritus and dated to 2310 BP and a more recently cut ditch sealed in by volcanic ash has been shown to have been in use prior to 1190 BP (Powell 1982b:216; Christensen 1975:33).

A number of smaller Highlands sites have also yielded pollen diagrams that date to around the Mid-Holocene. At Sirunki there is evidence for forest reduction that begins at around 4300 BP and from this time on, there was a general degradation of the forest, presumably due to anthropogenic influences (Swadling and Hope 1992:27). At Inim there is evidence of disturbance at about 2000 BP, and at Birip, clearance had probably occurred prior to the start of organic accumulation at around 2300 BP. This evidence provides a general picture of increasing human impact on forests, from around 5000 BP or just before, over a relatively large part of the central Highlands (Powell 1982a:29).
Figure 3. Archaeological sites in the Mount Hagen District.
(Golson 1976:207).

In the lower Jimi Valley in the mid-montane region (500m asl) north of Mt. Hagen, agricultural features again reputedly date to 5000 BP. These bear a satisfactory resemblance to gardening systems at Kuk, of a broadly similar age (Phase 2). This could suggest an alternative route into the Highlands fringe (Golson 1990:145). Today the highland fringe and adjacent lowland areas are dominated by primary forests supporting small dispersed populations of swidden horticulturalists and hunter-gatherers. The relict grasslands suggest more intensive past occupation. One extensive area of these fringe grasslands
occurs in the Ruti Flats, near the confluence of the Jimi and Lai Rivers. Modern
drainage ditches in the Yeni Swamp (east of Ruti) revealed heavily patinated
stone tools and associated prehistoric garden systems (Gillieson et.al. 1985:33).
In combination with pollen and sediment data, these artefacts provide the first
evidence for prehistoric agriculture and other activities in the lowland zone
(approx. 300,000 sq.km), of Papua New Guinea. Two artefacts have been
recovered from the spoil heap of a drainage trench in Yeni swamp. They include
a stemmed axe and a pebble chopper (both unifacially flaked), which were
found in the same sediment. These tools were similar to the waisted axes or
blades found on the Huon Peninsula, dated to around 40,000 BP, and at Kosipe
dated to about 26,000 BP. Tools similar to these have also been found at Yuku
rockshelter in the Mt Hagen area, and dated to c. 6000 BP. Like Yeni, these
tools are often found close to the margins of swamps with Pandanus groves
(Gillieson et.al 1985:33). Some unusual features in the trench wall at the Yuku
site were found and are believed to be similar to mound and hollow features in
the Wahgi valley. These features have been shown to be part of a prehistoric
water control system, dated to around 6000-5000 BP. The pollen and sediments
of Yeni swamp reveal a pattern of vegetation change and firing of the landscape.
The only previous evidence for prehistoric domestication of plants in the
lowland of Papua New Guinea came from the Aitape area of the Sepik basin.
Fragments of coconut shell were recovered from intertidal clays, dated at less
than 5000 BP. The sites in the Ruti area appear to be humanly constructed
swamp margin cultivation systems, and changes in the environmental record of
the Yeni swamp support human modification of the area at that time. Therefore,
it appears people were modifying the lowlands environment by clearance prior
to 3500 BP, while a second phase of clearance is indicated at c.1000 BP
(Gillieson et.al. 1985:36). The general appearance of edge-ground and quarried
fine-quality axe-adzes in archaeological deposits dated to around 6000-4500 BP
in various Highlands sites, and the application during the same period of

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grinding to the waisted blades at Yuku rockshelter, indicate that forest clearance was taking place on a large scale, presumably for agriculture (Bulmer 1982:195). This time frame supports the theory that agriculture occurred in the mid-Holocene, after transferring from Southeast Asia.

The fact that the majority of the evidence of forest clearance for agriculture spans the mid-Holocene (6000-4000 BP), lends support to the theory that it is within this time frame that humans were experimenting most with the development of agriculture. Questions have been raised as to why there is little or no information on earlier forest clearance in the pollen diagrams of the area. It is possible that the earliest indications of gardening would not be shown in the pollen diagrams if the first gardens were very small, short-lived and only very locally distributed. It is of course quite possible that humans were just not in the area in populations large enough to have affected the forests; that prior to 4500 BP, human influences did not alter the natural regeneration pattern of the forest. The earliest indications would be difficult to separate from the natural successional patterns which occur following climatic change (Powell 1982b:225). This could be one explanation why it was originally thought that agriculture only began in this time frame, and this could have biased this theory.

Another possible reason that it was originally thought that agriculture only began in the Mid-Holocene, is that artefacts (particularly wood) are not commonly preserved before 5000 BP. If a large collection of artefacts are found that date to the Mid-Holocene or later, then it could easily be assumed that this was the time that the most experimentation with agriculture was taking place.

The Austronesians may well have transferred out of Southeast Asia and into Papua New Guinea in the Mid-Holocene, along with their languages, various plant species, agricultural techniques and domesticated animals, but it is generally believed that some form of agricultural experimentation had already taken place prior to their arrival, and the evidence for this will be presented in the following section.
EVIDENCE FOR THEORY TWO

The majority of the evidence for the independent origins of early agriculture in Papua New Guinea, comes from the Highlands; in particular from sites in and around the Wahgi valley, near Mt. Hagen. Although there are now a number of sites and sources available for reconstruction within Highlands agricultural prehistory, the key evidence is still supplied by the Kuk swamp in the Wahgi Valley, as it has led to generalisations about the whole of Papua New Guinea's development of agriculture (Bayliss-Smith & Golson 1992a:1). The evidence from Kuk will form the greater part of this section. The sequence of agricultural systems in the Kuk swamp provides evidence that could be used to support a thesis of independent origins of agriculture in Papua New Guinea (Golson 1991:48).

The Kuk Site

Kuk is part of 180 sq.km. of swampland in the upper Wahgi Valley near Mt. Hagen, at an altitude of 1580 m. The archaeological appearance of agriculture at Kuk immediately after the Holocene (c.9000 BP) warm conditions were established has presented three possibilities for this area. These include i). that similar activities were developed earlier at lower altitudes and brought to the Highlands when conditions were more suitable, ii). that the Highlands population had developed agricultural techniques and adopted crops from the immediate forest during the late Pleistocene, but that these are not visible in the archaeological record, or iii). that the Kuk results really do represent the true beginnings of agriculture in Papua New Guinea (Yen 1982:293; Haberle 1993:109). All of these possibilities could support an internal domestication of plants within Papua New Guinea. So far, there is little archaeological evidence to support the first two options in this model, and from studying the information from Kuk, I am inclined to agree with the third possibility.
Beginning in the early 1970's, Jack Golson and colleagues excavated and recorded stratigraphy along 15 km of gridlike drainage canals at Kuk, providing as complete a view of successive intensive agricultural systems as anywhere in the world (Wilson 1985:92). There is convincing evidence for the first attempts at plant domestication and swamp cultivation starting at around 9000 BP, and followed by at least five phases of agricultural development in that part of the Papua New Guinea Highlands (Powell 1982b:217; Golson 1991:83). Each new phase appears more complex and sophisticated than the previous one (Gillieson et.al. 1985:32). The onset of the phases of swamp use and abandonment at Kuk have been seen as responses to stress in dryland cultivation caused by environmental changes that originated from human impacts (primarily agricultural impacts on dryland vegetation and soils), and to its alleviation by innovation in the dryland sphere (Golson 1982:297; Golson & Gardner 1990:405; Bayliss-Smith & Golson 1992a:1). The growth of agriculture gave rise to significant shifts in the ecology of the Highlands valleys, as the early agriculturalists were probably practising slash-and-burn or shifting agriculture (Foley 1986:276).

It has been assumed that a system of shifting cultivation with a long-term fallow was being practised at Kuk, before a general move to the use of swamps on the valley floor took place. The system of shifting agriculture typically consists of the partial or complete clearance of vegetation, burning of the debris, the temporary cultivation of an assemblage of crops in the cleared area, and the clearing of further forest for new gardens, while the old plot is abandoned to fallow under regenerating forest. The fallow is generally considerably longer than the period of agricultural use (Golson 1981b:43; Powell 1977:47). Although regrowth would occur on the land, it would not exhibit the richness of the primary forest because of the degraded state of the soil (Foley 1986:276). After repeated cycles of shifting agriculture and consequent regrowth, the regrowth itself would become increasingly degraded resulting in the grasslands.
present in the Highlands today. This process was probably intensified by the continual population increase made possible by agriculture. As the population grew, more and more land came under agricultural use, with the ultimate consequence of an increasing spread of the grasslands. The disappearance of much of the forest and the proliferation of the grasslands required the highland agriculturalists to devise new agricultural techniques fitted to the altered ecosystem (Foley 1986:276). The move to the swamps may be related to agronomic and/or social factors such as; the introduction of a new crop suited to swamp conditions (eg. taro), or the degradation of the soils on the slopes. Degrading soils would have lowered crop yields unless fallow periods were increased to maintain production. The reaching of the altitudinal limit of economic production of the cold-intolerant tropical crops, could also have been another reason for the utilisation of the swamps (Powell 1982b:218; Golson 1991:83). The greater fertility of the swamp soils had probably become known through experimentation, and therefore crop yields could be maintained with shorter fallow periods there compared with on the slopes. Population increase undoubtedly caused increased pressure on the land, and this in turn could also have led to the expansion into the swamplands for cultivation (Powell 1982b:218). In early interpretations at Kuk, the swamplands were not viewed as especially significant in their own right, but they were considered as supplemental to the dryland cultivation in areas surrounding the swamp (Feil 1987:23). At Kuk, the favourable ecological requirements for taro cultivation were ample and the elaborate drainage management suggests skilful manipulation to achieve optimum results of production.

Swidden farming is often considered to be the most rudimentary of all types of agriculture and therefore it is seen as the forerunner of all the elaborations that have since evolved. The direction of evolution is from extensive to intensive methods, towards closer control of the natural setting (Yen 1973:78). The drainage systems of Kuk swamp are a prime example of this
model, as they permit the use of land otherwise unsuitable for cropping. This measure of water control may then originate as an extension of the slash-and-burn regime, a quantitative addition on which intensive cropping would be applied because of the artificiality of its soil media (Yen 1973:78). The reconstruction from the swamp deposits at Kuk is one of continuous agricultural use of dryland from 9000 BP, associated with episodes of drainage of the swamp for purposes of cultivation. At Kuk, there existed a fairly consistent depositional pattern across the study area, indicated by the presence of several distinctive volcanic ashes which serve to represent various stratigraphic units. The lower three stratigraphic units of the site (the red-brown organic clay, the black organic clay, and the dark grey to slightly organic clay), are interpreted as inwashed sediments which accumulated at a rate of about 4 cm per 1000 years, from approximately 50,000 to 9000 BP (Golson 1985:308; Wilson 1985:92). It is these deposits that represent a record of the changing nature of the erosional agencies operating on the dryland environment (Golson 1985:308). The lowermost organic and inorganic sediments older than 9000 years, appear to be undisturbed and volcanic ash bands are more or less continuous and horizontally stratified within them (Powell 1982b:216). (see Figure 4.)
The evidence for the appearance of agriculture at Kuk is of three major kinds. The first is a highly distinctive grey clay, which appears in the sedimentary record in the swamp basin at c. 9000 BP. This clay is less organic than layers above and below, and it represents a phase of substantially accelerated deposition, due to an increased rate of erosion in the swamp catchments, where all the Kuk basin sediments come from. Forest clearance for agriculture is the most likely explanation for the increased erosion (Golson 1981c:55; Golson 1985:308; Golson 1991:84).
The second kind of evidence for the appearance of agriculture at Kuk is a 2m wide by 1m deep channel running across the swamp basin (Golson 1981c:55; Powell 1982a:217; Powell 1982b:28; Golson 1985:308; Wilson 1985:92; ). This channel is considered to be artificial and has also been dated to c. 9000 BP. The channel and associated features are interpreted as evidence for an early and short-lived episode of swamp management for agriculture, and the grey clay is believed to be the erosional product of continued dry land gardening deposited in the swamp when the early drainage system fell into disuse (Golson 1991:84). Yen (1990:262), believes that the first phase (9000 BP) has an "experimental appearance", with planting surfaces intrinsically uncontrolled but with sufficient drainage provided for wet and dry plantings, while the more structured arrangements of the second management phase in the swamp (6000 BP) essentially mimic the first phase. Golson (1991:84) has stressed the artificiality of these channels and ditches of the 9000 BP level, to try to interpret them as evidence of agriculture in the form of a new type of activity, and not just as the continuation or transformation of some strategy already in operation within the general Highlands region.

From about 6000 BP, there are a number of clearly artificial channels dug across the Kuk basin, with the aim of assembling the water flowing in from the major catchment of the swamp and disposing of it beyond, thereby making the area suitable for cultivation (Golson 1981c:57; Golson 1985:308). The 9000 BP channel is thought to be an earlier example of the same thing. The final form of evidence are certain features chronologically associated with this channel. These include shallow basins, pits, gutters, hollows, stakeholes, and possibly pig wallows which could represent the evidence of agricultural activities on land surfaces near the channel, or the presence or domestication of pigs (Golson 1981c:55; Powell 1982a:217; Golson 1985:308).

Golson has set out six phases of swamp drainage at the Kuk site in Table 2. (Golson 1981c:57; Golson 1982:300; Powell 1982a:217; Wilson 1985:92 ).
Phase 1 is represented by the deep artificial channel cut into the underlying dark grey to black clay, which has been dated to 9000 BP. The ditch was filled with inwashed plant litter, overlain by the grey clay, and a number of features associated with this ditch (basins, gutters and pits), bear similarities to later water management features and pig wallows (Golson 1985:308; Wilson 1985:92). Phase 2 appears above this first grey clay unit, as a second series of archaeological drains and features dated to about 6000 BP. Several drains are dug from the inlet of the area’s major catchment, across the swamp to its sluggish outlets. The Phase 2 archaeological features separate the grey clay unit from a superimposed black clay (Wilson 1985:92). The beginnings and/or ends of some of the drainage phases have been seen as correlating with events in the general environmental record. For example; the beginning of Phase 3 shows a low point for forest values in the pollen diagrams at about 5000-4000 BP (Wilson 1985:92; Golson 1990:143). The pollen diagrams showing a depressed ratio of forest to woody non-forest types suggest that considerable inroads had already been made into primary forest at this time, presumably as a result of clearance for agriculture (Golson 1985:309). The end of Phase 3 (c.2500 BP) is marked by a stratigraphic change from clay particles to soil aggregates, which has been interpreted as due to the advent of tillage in the agricultural technology (Powell

<table>
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<th>Phase 1</th>
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<td>Phase 2</td>
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<td>Phase 5</td>
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<td>Phase 6</td>
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Table 2. Six Phases of prehistoric swamp use at Kuk.
Golson (1982:302; Bayliss-Smith and Golson 1992a:3) interpreted the change to soil tillage as one due to an important innovation in dryland cultivation technology, following the final replacement in the local areas of forest by grassland. As grassland soils are seen as relatively infertile and difficult to cultivate, soil tillage is seen as a necessary response to the need for a technology to enhance roots from grass fallows (Bayliss-Smith and Golson 1992a:3). It has since been shown that the deposits of soil aggregates were being laid down on the black/dark grey clay surface before the Phase 4 ditches were being dug (Bayliss-Smith and Golson 1992a:6).

Phase 3 also lacks the specialised features of the earlier phases and it is considered that a mixed farming regime was the most likely agronomic system practised at this time (Powell 1982a:217). If the stratigraphic break in Phase 3 from deposition in the form of clays to deposition in the form of soil aggregates does represent the appearance of soil tillage in the agricultural technology, then this would indicate that stabilised grasslands had become established in the valley bottom by 2500 BP (Wilson 1985:92; Golson 1990:144). The replacement of forest by grasslands indicates the disappearance of wild sources of protein and paves the way for an intensification of pig husbandry in replacement, in the time frame of the last three phases (Golson 1990:144). It is believed that pig husbandry has to be supported to some extent by produce from gardens, and therefore there was an advantage for those communities able to expand production by intensive cultivation of richer soils, of which drained swampland is a good example. It has been suggested that taro would have been a particularly appropriate crop in swamp cultivation (Golson 1990:144). If agricultural people were the main agent for forest destruction then some form of dynamic equilibrium achieved in the vegetation of the upper Wahgi must have resulted from some change in human agricultural activities. It has been proposed that Phase 3 registers this change (Golson 1981c:60). It indicates that the pressures behind forest clearance were accommodated by this time, by draining
and reclaiming large areas of land for agricultural use. Phase 3 seems to have lasted a long time, from almost 4000 BP until 2500 BP, and this may be seen as a successful response to environmental degradation. It was during Phase 3 at Kuk that the partial recovery and stabilisation of the forest values were achieved. From the pollen diagrams, this has been interpreted as successful forest regeneration on the hill slopes, combined with their continued agricultural use (Golson 1982:60).

The earlier drainage phases at Kuk (Phases 1-3) are significantly different from the later ones, as they are simpler in drainage organisation and they appear to be separated by longer periods of inactivity in the swamp. Their structural features are not linear and uniform, but consist in part of small basins and inter-connecting runnels (small channels), which can admit and circulate water as well as dispose of its excess. These earlier systems are thought to represent mixed gardening, not mono-cropping, with the inter-cropping of different plant species, and allowance for their varying soil and moisture requirements (Golson 1982:300; Golson 1990:145). In Phases 2 and 3, the channels and basins designed for the wet crops were planned as irrigation devices, allowing water once it had entered the system from the larger channels, to slowly flow back through them (Golson 1981c:57; Bayliss-Smith and Golson 1992a:2). In Phase 3, dry cultivation may have been carried out in regular plots formed between straight gutters intersecting at right angles, physically separate from chains of small inter-connected basins, probably for the water-tolerant crops (Golson 1981c:57). This feature makes it highly likely that taro was prominent amongst the water-tolerant plants being grown. As mentioned in the preceding chapter, the exact origin of taro is currently under debate. Questions have been raised as to the origin of Colocasia taro, which has often been proposed for these claimed early wetland gardens at Kuk. Colocasia taro is found wild and cultivated from as far afield as India, right across to Papua New Guinea and Australia. The
results of recent chromosome studies raise the possibility of two separate domestcations, one in Asia and one in Papua New Guinea (Golson 1991:48).

The questions of the geographical origin of taro have failed to show whether they mean the origins of taro as a natural species, or the origins of varieties of cultivated taro. Matthews (1991:69) believes that the cultivated varieties must have originated within the natural geographical range of the species, if *Colocasia esculenta* originated somewhere as a natural species, and the geographical range was not extended by humans before its cultivation. Observation of other *Colocasia* species and wild taro, suggests the possibility of a natural range extending from northeast India, to Australia and Papua New Guinea. If taro was this widespread before its cultivation, then today's cultivated varieties may have diverse and independent origins (Matthews 1991:69). One opinion is that taro was the vehicle on which the drainage development occurred in the highlands, as it is believed that the soil imprints in the early phases could have represented the traces of domestication, or the early cultivation of highland domesticates; for example, *Australimusa* bananas, in an agriculturally formative period (Yen 1982:292).

It is probable that these early cultivation systems supported smaller and less dense populations than in present times, and that there was less impact on the environment. In this environment it would still have been possible to obtain wild plants and animals, including perhaps feral pigs, so that pig husbandry is not likely to have been very systematic (Golson 1990:145).

Phases 4-6 have been interpreted as representing the development of the pig-centred societies that are present in the area today (Golson 1990:145). Phase 4 can be interpreted as a combination of a crisis in dryland agriculture, and the incentive to reclaim wetlands for high yields and surplus production to sustain pigs (Bayliss-Smith and Golson 1992a:15). In the early part of the sequence, Golson interprets the basin-like soil imprints as indications of pig wallowing, and calls on evidence from other archaeological sites for the presence of pigs in
the highlands as early as 10,000 BP. The agricultural connection is that pigs (not indigenous to Papua New Guinea), form an inevitable association with plant husbandry (Yen 1982:293). Phase 4 was originally interpreted as a specialised system of taro production, at the intensive level now necessary to maintain not only people, but also pigs; and pigs in greater numbers than previously, because of their likely importance in mediating transactions within and between social groups. Phase 4 is also seen as a more intensive drainage regime than Phase 3, as its disposal channels and field ditches indicate that larger areas than before were in simultaneous or at least coordinated use. As mentioned above, taro has been suggested as the specialised wetland crop, with yams (*Dioscorea* spp.) as the dryland counterpart (Bayliss-Smith and Golson 1992a:2).

**Pigs in Papua New Guinea**

The question of the antiquity of pigs in Papua New Guinea is still a matter of dispute, with some scholars claiming that pigs have been present in Papua New Guinea since the Late Pleistocene / Early Holocene (Bulmer 1982:188), while others claim that pigs only really show up in the archaeological record in the Mid-Holocene (Shutler 1978:221). I see the options as 1) pigs were either self-introduced into Papua New Guinea in the terminal Pleistocene / Holocene period or introduced as domesticated animals in this same time frame (and possibly with agriculture) or 2) pigs were self-introduced into Papua New Guinea in the Mid-Holocene or were introduced as domesticates at this time.

When Yen (in Golson 1982:298) originally asked to consider the possibility that the imprints in the 9000 BP horizon in the Kuk deposits were due to the cultivation of Papua New Guinea native plant species, it was commonly believed that Papua New Guinea was in the presence of Southeast Asian domesticates. Taro was believed to have been one of these domesticates, and at this time it was accepted without question to be of Southeast Asian origin. This belief was largely due to the claim that pigs were present in the Highlands at
around 12,000-10,000 BP (Bulmer 1982:188). There are claims for the presence of pigs in two Highland rockshelters; Kiowa and Yuku, dating to around the terminal Pleistocene / Holocene period. A single incisor has been found at each site; one in Layer 5A at Yuku (dated 12,000-10,000 BP), and one in Layer 12A at Kiowa (dated to 10,350 BP). The argument was that since the pig is not a native animal to Papua New Guinea, then it was hardly likely to have made its own way across the water barriers of Eastern Indonesia (Golson 1982:298). Instead, it was believed that the pig came into Papua New Guinea as a husbanded animal, and since there is now such a connection between pigs and agriculture in Papua New Guinean and Oceanic systems, its appearance implies the simultaneous arrival of plants of Southeast Asian origin, such as taro and yams (Golson 1982:298). Although this is very limited evidence, it is believed that if the pig was self-introduced into Papua New Guinea, or brought as a domestic animal by humans, then there is little objection to its reaching the Highlands by this period (Bulmer 1982:188; Christensen 1975:33). If a Southeast Asian animal had been introduced into Papua New Guinea around the end of the Pleistocene, then it was plausible to think that Southeast Asian plants (taro(?) or yam) might be incorporated in or responsible for the agriculture claimed at Kuk, for 9000 BP (Golson 1989:680). If this can be shown to be true, then the theory that agriculture arose in Papua New Guinea in the Early Holocene independent of Southeast Asian influences, becomes debatable. It then becomes possible that agriculture diffused out of Southeast Asia and into Papua New Guinea in the terminal Pleistocene/ Holocene period, and not just during the Mid-.Holocene, as was originally thought. As it is, taro has been claimed as the crop under cultivation in the 9000 BP gardens at Kuk, yet its origin is still a matter of dispute. It may be that taro did actually originate in Papua New Guinea and was already exploited as a domesticated plant prior to the introduction of Southeast Asian plant species.
The major question is whether the evidence may be used to adduce the early adoption of pig husbandry. For instance, was there already established by 9000 BP an agricultural support for subsistence that marked an incipience of the important social role of pigs that is so evident in Papua New Guinea today? (Yen 1985:318). Bulmer (1982:188) agrees that pigs could have accompanied agriculture into the Highlands, either as a domestic animal or as a wild bush-fallow volunteer, in the terminal Pleistocene/Holocene period.

Another theory concerning the antiquity of pigs in Papua New Guinea, is that the pigs teeth dated to the Early Holocene may also have found their way to the Highlands as ornaments, through trade or exchange routes and therefore need not necessarily indicate the presence of pigs, nor agriculture in the Highlands in the terminal Pleistocene/Holocene period (Bulmer 1982:188). However, the presence of the Kuk swamp gardens do indicate that agriculture was developed at this time (9000 BP), and therefore the introduction of pigs with Southeast Asian cultigens may have just reinforced the initial horticultural base already present. However, the teeth do imply that pigs were present somewhere in the island of New Guinea. The teeth found in the rockshelter deposits have not determined whether the pigs were domesticated or whether they were wild, feral types. Future research may be able to determine this factor, and as a result may be able to show whether pigs accompanied humans and cultivated plants into Papua New Guinea in the Early Holocene, or whether they made the sea-crossing on their own.

Contrary to earlier beliefs, wild populations of pigs were present in western Indonesia to as far east as Sulawesi, while they were absent in many parts of the Philippines, the Lesser Sundas and Moluccas, and in Oceania (Bellwood 1976:221). Pig bones in archaeological deposits beyond Sulawesi not only strongly indicate transport by humans, but if there are grounds for considering them to be domesticated, then they may also indicate the existence of plant cultivation, as noted above. It is believed that pigs in captivity need to
be fed to some extent on food that is actually produced by humans (Bellwood 1976:162).

Despite the evidence for the early Holocene claims for pigs in Papua New Guinea, most of the reports for the presence of pigs in Papua New Guinea are from 6000-5000 BP (Shutler 1978:221; Foley 1988:159). The presence of pigs at this time were presumably directly associated with the development of agriculture. The pig may even have been introduced more than once, and it is possible that those present at around 6000-5000 BP were domesticates (Shutler 1978:221). Kelly (1988:159), believes that pigs were probably never an important component of the diet of Highlands peoples, as wild pigs are generally not abundant at altitudes above 1000 m and are sparse or absent above 1500 m. While isolated specimens of pig bones have been dated to 10,000-9000 BP (at Highlands sites containing remains of game animals), the majority of small quantities of pig are represented from levels dated to 6000-1000 BP. Generally, the evidence suggests that wild pigs were not present in the Highlands in sufficient numbers to constitute a significant contribution to the diet, prior to the Mid-Holocene (1988:159). Secondary forest and grassland provide suitable foraging areas for Highland pig populations that have been studied ethnographically, and this indicates that wild pigs were more than likely sparse prior to the forest clearance that commenced around 5000 BP (Kelly 1988:159). At around 6000 BP, the swampland gardens exhibit distinctive features thought to be associated with the cultivation of taro. This development is roughly contemporaneous with the expansion in the Highlands archaeological record of the remains of pig. The cultivation of taro would have permitted the domestication and husbandry of pigs on a larger scale than would have been previously possible (Foley 1986:276). The belief that pigs were not present in large numbers in the Highlands of Papua New Guinea until the Mid-Holocene, lends support to the theory that agriculture developed as an internal process in the Early Holocene.
Despite the fact that the origin of taro is debatable, the origins of some other plant species (yams, some bananas etc), being Southeast Asian does not conclusively prove that Papua New Guinea's agricultural origins were dependent on Southeast Asian plants. The extent to which plants indigenous to the island are cultivated in gardens in Papua New Guinea presently, makes it reasonable to assume that agriculture could have begun in Papua New Guinea independently of Southeast Asia (Golson 1981a:34).

The name *Sus papuensis* was originally given to the species of pig in Papua New Guinea, but it has since been shown that this is incorrect. It was originally thought that the Papua New Guinea pig was an eastern version or a feral form of *Sus scrofa*, as these early views were based on the canine and skull characteristics (Groves 1981:23). The Papua New Guinea pig displays characteristics of other species, most notably *Sus celebensis* and *Sus scrofa / Sus s. vittatus*. The whole suite of characteristics of the Papua New Guinea pig sorts into three groups; those with characteristics like *S. celebensis*, those like *S. vittatus*, and those between the two. There were two alternative hypotheses for the species of pig in Papua New Guinea. The first was that *S. Pauensis* was a surviving primitive species related to the common ancestry of *S. scrofa* and *S. celebensis*. The second hypothesis was that this species of pig was a hybrid between them, and it is this theory that has now been shown to be correct. This was shown by the fact that both presumed parental forms are now known to have existed in the past in a domestic state (Groves 1981:66). It is possible that the introduction of a new species of domestic pig lead not to the replacement of the old one, but to a hybridisation. There is no firm evidence of one or the other parent species of *S.papuensis* having pre-existed in Papua New Guinea, and the likelihood of an immigrant form mixing over the entire island of Papua New Guinea with an indigenous form is small. Groves (1981:66) hypothesised that the crossing of this species of pig took place somewhere in the Moluccas in Indonesia. Therefore the pig in Papua New Guinea is now seen as a cross...
between *Sus scrofa vitattus* and *Sus celebensis*. Pigs are omnivorous, and they root around in and on the ground for tubers, bulbs, nuts, seeds and will also eat small vertebrates. Their lower incisors are cylindrical and become chisel-like on wear, while the upper incisors are low, blunt blades (Hillson 1986:90). The timing of the sequence of pigs teeth formation is believed to be considerably different in ancient pigs, from present domestic pigs. Domestic pigs show a number of differences in the teeth, in particular a reduction in molar area and in the size of tusks. The early process of domestication seems to have involved a reduction in size, in a number of mammal species. In pigs, size reduction seems particularly to have involved the length of snout and jaws (Hillson 1986:254). Snout shortening with domestication, is associated with tooth size reduction. There is a general difference between wild and domesticated pig (*Sus scrofa*) in body size and proportions, but so far, archaeological deposits have not yielded enough faunal evidence to show whether the pigs in Papua New Guinea were domesticated or wild types.

Humans developed the effective and diverse techniques of pig husbandry used in various parts of Papua New Guinea, and helped to create ecological conditions favourable to both domestic and feral pigs (R. Bulmer 1982:62). Faunal impoverishment following on from forest disturbance has been suggested as one reason why pigs have come to be so important in many Highlands areas. Losses of wild fauna were apparently met with more intensive management of pigs. It has also been suggested that favourable conditions for a forest-based pig husbandry in the Highlands were provided as secondary forest expanded with agricultural clearance (Bayliss-Smith and Golson 1992a:2). When the availability of forage was reduced by increases in human populations, there was a substitution of fodder for forage, and a consequent intensification of agricultural production, in order to retain existing ratios of pigs to people. It was with this process that full pig domestication occurred (Golson and Gardner 1990:402). It has been argued that the retreat of forest directly led to changes
which required the full domestication of pigs, if existing ratios of pigs to people were to be maintained. As the availability of forage in secondary forests declined there arose the need to substitute for forage, through the surplus production of root crops. It is now seen as this fodder-based husbandry that allowed a system of social transaction to be established, based on the exchange of pigs. From c. 2000 BP onwards the upper Wahgi provided all the necessary pre-conditions to enable this transition to take place; towards a society where pigs became much more important as objects of prestige and in relations between social groups (Bayliss-Smith and Golson 1992a:2). I believe that currently, most scholars would accept the presence of pigs in Papua New Guinea back to 6000 BP, yet reject S. Bulmer's claim for the terminal Pleistocene. Should the pig prove, however, to have been in Papua New Guinea by 10,000 BP, then it must have almost certainly been introduced as a hand-fed animal by people, given the water crossing that would have had to be made. In this case, there is a possibility that cultivated plants involved in foddering pigs and feeding people, would also have been brought along (Golson 1991:48). If this is shown to be true, then the whole theory about whether agriculture developed independently of Southeast Asian influences in the terminal Pleistocene/Holocene period would have to be rethought. However, until it can be shown that pigs were definitely in the Highlands with the advent of agriculture at that time, it does not rule out the possibility that agriculture could have developed as an internal process within Papua New Guinea, independent of Southeast Asia.

Golson and Gardner (1990:2), argue that developments in the spheres of environments, agriculture, pig husbandry and exchange were all interconnected, and that they all came together in the upper Wahgi valley around 2000 BP to effect a radical reassessment of the value of the wetlands, of which Phase 4 was the first expression. A long history of vegetation change occurred under agricultural influences or clearances, in the course of which agricultural yields declined as forest fallow gave way to grassland cultivation through a sequence
of ever more degraded secondary growth and soil deterioration (Golson and Gardner 1990:2).

The drainage ditches in Phase 4 can be divided into three types. These are major disposal channels, large field ditches and small field ditches. The major channels are designed to intercept water from the southern apex of the fan and to channel it towards outfalls to the northwest and northeast (Bayliss-Smith and Golson 1992a:5). The ditches of Phase 4 are more modest features serving as the perimeter drains of small fields or planting beds. The drains are more narrow and deeper than they are wide, and they interconnect with each other at right angles, to form networks which ultimately drain towards the major disposal channels (Spriggs 1982:5; Bayliss-Smith and Golson 1992a:5). The whole forms a rather open network whose repetition over large areas suggests single crop plantings. If the case of deteriorated conditions in the swamp is correct, the obvious candidate once again is taro (Golson 1981b:58; Golson 1982:300; Powell 1982a:217). Phase 4 at Kuk came to an end shortly before the fall of the distinctive Olgaboli tephra which took place around 1200-1100 BP. Phase 4 at Kuk provided its inhabitants an opportunity to grow taro as a staple crop, as this opportunity was denied on dryland due to the ecological problems from deforestation (Bayliss-Smith and Golson 1992b:21).

During Phases 4-6 the drainage works are more elaborate, almost as if the wet land had become progressively more difficult to manage; while they are also more coordinated as though it were necessary to have a larger area within a system at one time. At first a single drainage channel seemed to have sufficed, though they may have become larger with each successive phase. The last three phases see the appearance and development of large tributary drains feeding the water from large areas into a major channel, with more than one perhaps operating at any one time (Golson 1981b:56; Powell 1982a:217). Sweet potato has been proposed as the staple crop for Phase 6 (Powell 1982a:217; Spriggs 1982:9).
The patterns in the initial three Phases are diverse and apparently represent cropping of a variety of plants; as yet unidentified. In the last three Phases of the swamp drainage, the swamp agricultural systems become more intensive with more densely constructed drainage features and grid-like garden plots (Wilson 1985:92). The greater fertility of the swamp soils had become known through experimentation, after the third phase of the cold-intolerant crops had been reached, and therefore crop yields could be maintained with shorter fallow periods there, compared with on the slopes. The populations had likely increased and this resulted in considerable pressure on the land (Powell 1982:218). Phase 5 apparently has the same character as Phase 4, although some of the garden ditches become wider, shallower and flat-bottomed, and the network appears to be less open. Phase 6 sees an intensification of the developments that took place over the two previous phases. The network of garden ditches becomes tighter and it becomes more grid-like, as in a pattern of gardens and intervening ditches characteristic of dry-land sweet potato cultivation in the upper Wahgi valley today (Golson 1981b:58). There is no doubt that Phase 6 (250-100 BP) is for the incorporation of the sweet potato into the agricultural system. The gardens grid-like composition and the whole drainage network is intensified to provide for the new plants sensitivity to water. There is also a dramatic reduction (by 2/3), in the areas of swamp under drainage (Golson 1981b:58), and houses also appear in the swamp itself for the first time in the history of the Kuk sequence. Only in Phases 5 and 6 are wooden tools preserved, however. This is probably due to the decay of older timbers as a result of their drying out when the water table dropped during episodes of swamp drainage. The most common finds so far have been men's heavy digging sticks, long paddle spades, and women's digging sticks, representing the tools with which the swamp was drained and cultivated (Golson 1981b:59; Powell 1982b:28). Ethnography was used to interpret Phase 6 at the Kuk Swamp, as it was seen as an intensive phase of the local agricultural system; a view supported
by the location during this phase, of men's and women's houses in the swamp which were identical in type with those described by the first Europeans (Golson 1990:141). Other components of the agricultural system would have been located on the neighbouring dryland, of which any forest would have been cleared and replaced by natural regrowth of degraded secondary communities and grass, with managed plantings of *Casuarina* and other trees. This would have been associated with at least moderate densities of population (Golson 1990:141). The ethnographies showed that not all the sweet potato was grown to support the human populations, but that at all times a proportion was grown for pigs. This ethnographic situation has created a problem for the upper Wahgi however, for at the time of European contact there was no swamp drainage at Kuk (Golson 1990:141).

The Kuk drainage record has been characterised as revealing an evolutionary sequence of intensification in the sphere of production, following on from independent origins of agriculture in Papua New Guinea and based on the domestication of a suite of plants that included basic staples, vegetables and fruits, able to sustain populations in various environments (Golson 1990:145). Yen (1982:291) is a strong advocate for an evolutionary nature of the drainage systems, and has suggested that domestication likely began in the "variable ecologies of mid-altitude regions", with the development of "simpler regimes of swidden modes of agriculture" following the "long hunter-gatherer phase". The increasing "specialisation" of the environment signalled the accommodation of taro as a crop (Yen 1982:292). The drainage systems excavated at Kuk suggest incipient agriculture, a more settled population, and densities significantly higher than those associated with simple hunting and gathering (Kelly 1988:159). The Wahgi cultivations show a series of adaptive re-designing of drainage and water-control ditching, which appear to be aimed at coping with changes in sedimentation and water level, induced by cultivation at this site and on hill slopes above (Bulmer 1982:203). One explanation of this process of
adaptation is that it is most likely that the Wahgi cultivations were designed for use of the tropical crops of Southeast Asian origin, which were at the upper limits of their effective cultivation in the intermontane valleys, and which therefore required special cultivations techniques to ensure their maximum productivity (Bulmer 1982:203).

The archaeological evidence at Kuk should not be seen as permanent swamp cultivation for a prolonged period, nor as a single episode of swamp use. It appears to represent a system of land recycling through swamp fallow, enabling a change from a system of land recycling through forest fallow which was no longer viable (Bayliss-Smith and Golson 1992a:15). Gorecki (1986:163) on the other hand, believes that the swamp cultivation in the upper Wahgi Valley was actually continuous from c. 9000 BP onwards, but that it shifted from one location to another within and between swamps, and that the gaps in the sequence represented by the long periods of non-use support this.

Bayliss-Smith and Golson (1992b:23), believe that wetlands were an environment which challenged prehistoric societies in a distinctive way that tended to produce a distinctive outcome. The social and political structures encouraged by the needs of wetland drainage may be rather different in character from those found in hydraulic societies (where irrigation is most developed in places and periods where power is the most centralised ie: Polynesian chiefdoms). Wetland drainage can be simple in its technology and incremental in its evolution, and it does not necessarily require large-scale territorial control, centralised management or forced labour. Therefore drainage activity will tend to encourage the development within communities, of reciprocal and cooperative relationships. Land management practices such as wetland drainage is a fine example of the collective management of a common property source (Bayliss-Smith and Golson 1992b:23). Feil (1987:24), suggested that the intensive use of the Kuk swamplands provided favourable conditions for large, compact communities to have been supported. It was also
likely that the Western Highlands was the genesis of the cultures where resources beyond the level of subsistence were mobilised for large-scale political and ritual enterprises involving pigs and other values.

**Other Areas of Early Holocene Agriculture in PNG**

The palaeobotanical record in the Wahgi valley is a general one for the Western Highlands. The archaeological/geomorphological record is mostly restricted to Kuk, but there is evidence from other sites of swamp drainage to suggest that the Kuk sequence is reflecting processes of a general character (Golson 1990:143).

The site of Wañilek is at 1675 m altitude, in the upper Kaironk Valley in the Madang Province. This site is physically closer to the lowlands than the Central Highlands, and it is notable in its evidence of an early hunting and gathering settlement, including post holes dating to between 15,000 and 12,000 BP. The most important dates from this site however, are between about 5500 and 3000 BP, when Wañilek was a settlement of intensive cultivators who were possibly recultivating grassland, resulting from earlier forest clearance by swidden cultivators (Bulmer 1977:61). There is archaeological evidence at Wañilek which provides information about the stone technology of the period between 5500 and 3000 BP, which suggests the presence of agriculture during this period. This new stone technology was coupled with the settlement of the cultivators, which included polished axes and woodcarving chisels, drill points and tanged cultivating tools. The evidence suggests that at least one part of the site was cleared, down to bare subsoil as a house site almost 15000 years BP (Bulmer 1977:62). Since this find, houses and other structures have been built periodically, and there is a series of post holes, mostly from pointed poles 5-10 cm in diameter, set into the subsoil. In the earliest soil there is a small number of very large post holes for which there are no current parallels, and one has been dated by its charcoal contents to about 15,000 BP. There are a number of
stratigraphic layers at Wañlek, which suggest a series of occupations. Pole structures, fireplaces and ovens associated with stone artefacts indicate that the site was settled from about 5500 to 3000 BP, as previously mentioned. A truncated garden soil on the top of the above layers indicates the site was later cultivated; from around 3000 BP onwards. A consolidated surface on the top of the garden soil suggests a period following cultivation, when the site was unoccupied. Most of the stone artefacts from Wañlek come from the deposits relating to the occupation between about 5500 and 3000 BP. They include remains of the manufacture at this site of polished axe-adzes and wood-carving chisels, flake scrapers, drill points and tanged cultivating tools. Bulmer (1977:66), states that “the Wañlek site artefacts comprise assemblages that should be considered as coming from a general habitation site, as they reflect a range of activities typical of an agricultural settlement.” The Wañlek tools were made of slate, whereas most other tools were presumably made of wood, which could be one reason why so few have been found. The Wañlek cultivating tools generally have two shapes of cutting edges; either a very broad convex edge, or a wide point. The Wañlek tanged tools have heavy use smoothing along their cutting edges, which is believed to be characteristic of tools used for digging in the ground; for example tilling, ditching and digging for roots. These tools also appear hafted, after it was shown that they are carefully retouched with smoothed tangs (Golson 1981b:51; Bulmer 1977:66). It appears that residential sites of swidden agriculturalists may have left little evidence on the ground, but it is possible that the valley was first cultivated between 9000 and 6000 BP, which is similar to evidence for Kuk in the Wahgi valley. Even though the majority of the dates for occupation at the site of Wanlek span the Mid-Holocene, which could lend support to the theory that agriculture only developed at this time, it cannot be disputed that its older date is similar in age and stratigraphy to the major site of Kuk.
The establishment of gardens at the higher altitudes of Wahgi and Kaironk may have been aided by the warmer, wetter climate around 9000-5000 BP, and the earliest cultivations may have been the local domestication of native plants like the nut and fruit trees, and not necessarily species of Southeast Asian origin (Bulmer 1977:69). This development could be seen as the domestication of useful parts of a hunting-gathering flora. The process of domestication may have begun, and would have been a more logical sequence of events, earlier than drainage manipulation of the environment. Drainage means the tailoring of one particular feature of the environment to the requirement of a species or a suite of species (Yen 1982:293). From the Kuk site, it was presumed that the major crops under cultivation there were brought up from lower altitudes as temperatures improved at the end of the Pleistocene. In the lowlands it is possible that by the time the Southeast Asian yams, bananas, and taro were transferred to Papua New Guinea, some form of subsistence and domestication of species was being practised. The establishment of taro, yams and bananas in rainforest communities, widespread by 8000 BP, would have been relatively simple, particularly if some form of subsistence agriculture was already being practised (Powell 1977:18). There is very little relevant evidence from such lower altitudes so far. The single agricultural sequence known from the Highlands fringe (500 m altitude), does not begin before 5000 BP and so far there has been no equivalent record at all from the coast (Golson 1991:48). The earliest evidence for trade between the peoples of the mountains and the lowlands is from a montane site that contains marine shell in a layer over 9000 years old. By 6000-5000 BP, rock was being quarried at a number of montane localities and traded between mountain groups and to the lowlands. Ritual may have played an important role in the trade and exchange of goods (Bulmer 1977:71).

The plants likely to have been important in early Papua New Guinea agriculture, whether exotic or indigenous are tropical and most of them are
intolerant of frost. In the Wahgi valley now they approach within 600 m of the ceiling of their productive growth and at around 9000 BP the temperatures were only just those of the present day after the cold climate of the Pleistocene (Golson 1981b: 56; Golson 1985:309). The evidence for lowland agriculture is fairly scarce, and the evidence for occupation of the Highlands before Kuk is somewhat minimal also. It is possible that the agriculturalists at Kuk derived from populations following the slow upward movement of vegetation as climate improved, and entered into environments where previously few people had lived and possibly not year round (Golson 1981c:56). The reasons for the periodic use and non-use of the Kuk swamp for agriculture, are firmly rooted in the complex relationships between humans and the land (Golson 1981c:56).

Why is there no evidence on early forest clearance in the pollen diagrams? The archaeological evidence from Kuk suggests that gardening was being practised in the Wahgi valley some 9000 years ago, while the pollen diagrams only indicates that clearance of forest for agricultural purposes occurred at some time prior to 5300 BP. It is possible that the earliest indications of gardening would not be shown in the pollen diagrams if the first gardens were very small, short-lived and only very locally distributed. This could be a major point to consider for the possibility of even earlier horticulture in Papua New Guinea. Perhaps the drainage systems at Kuk are not the earliest forms of domestication and cultivation in Papua New Guinea, but others just have not been found yet. Prior to 4500 BP human influences may not have altered the natural regeneration pattern of the forest. The earliest indications would be difficult to separate from the natural successional patterns which occur following climatic change or catastrophic events; for example, volcanoes or earthquakes (Powell 1982:225).
RESULTS OF AGRICULTURE IN PAPUA NEW GUINEA

It is clear from pollen analytical research that the open landscapes which form the agricultural setting are the product of millennia of history, and it is generally agreed that the major agency in their creation out of an originally forested environment was sustained clearance for cultivation. The technical features of traditional Highlands agriculture were designed to ensure the productivity of agriculture in conditions of grassland and degraded growth, yet they were responses to circumstances of increasing and irreversible deforestation, brought about by the practice of agriculture itself (Golson 1989:683).

The vulnerability of the montane forest to disturbance was compounded by the fact that, because the disturbance was due to agriculture, it was repeated. Shifting agriculture, which is inferred for the early stages of Papua New Guinea's Highlands agriculture, depends for its performance on the regeneration of the forest, and on the abandoned gardens which have been created by its clearance (Golson 1982:302). Since the regrowth of montane forest is retarded by the effects of altitude, early agriculturalists in Highland Papua New Guinea must have had to make extensive use of country to allow regeneration to proceed. Because of the topography of the region and the altitude, limits would have been set by climatic and environmental disabilities of various kinds (Golson 1982:302). Once these limits were reached, the agricultural process was turned inwards, and repeated clearance of the same land at shorter intervals would have upset the orderly succession of forest regeneration on which the agricultural system depended.

It has been observed that given what is known of the performance of crops like taro in the Highlands, there would have been great differences in the productive capacities of different communities, depending on soil conditions and altitude. Those communities on the valley floor with access to swamplands
would have been among the most advantaged (Foley 1986:277). This would have resulted in higher population increases in these areas, and also allowed the maintenance of large holdings of pigs. This in turn, would have increased the differential advantages and prestige of these communities still further. This concentration of large, well-fed, prestige populations, often on the valley floor, opposed to smaller, weaker populations higher on the slopes, has important implications for the movement of peoples in the Highlands (Foley 1986:277).

The progressive alteration of the forest cover brought about by shifting agriculture had effects on the distribution and availability of the plant and animal resources. It is certain that as secondary growth in agriculturally exploited areas became more widespread and more degraded, bush resources became fewer and less varied. Widespread evidence for treeline disturbance by fire from 5000 BP, could be evidence for the beginnings of such exploitation as a direct result of resource impoverishment in the agricultural zone. With the appearance and spread of grassland, bush resources vanished and were not replaced (Golson 1982:303). Environmental modification slowly became environmental transformation (Golson 1982:303).

One environmental change directly related to humans own interference with the landscape, is the process of erosion and sedimentation of the river valleys and coastal plains. The silting up of valleys and the extension of swamps affected transport, communications and land use (Bulmer 1982:203). The agricultural utilisation of a natural ecosystem may be accomplished by manipulation rather than transformation; not by drastically changing its diversity index, but by altering selected components without fundamentally modifying its overall structure (Harris 1969:6). Instead of an artificial ecosystem being created to replace the natural one, cultivation may proceed by substituting certain preferred domesticated species for wild species that occupy equivalent ecological niches. Swidden cultivation and fixed-plot horticulture manipulate the generalised ecosystems of tropical forests in this way, and in doing so, come
closer to stimulating the structure, functional dynamics and equilibrium of the natural ecosystem, than any other agricultural system humans have devised (Harris 1969:6). Some possible spatial variations with more immediate ecological consequences arising from horticultural intensification were, increases in the area of cultivated land, the emergence of permanent settlement groups, less dependence on other older, subsistence root crops, more complete tillage, cultivation of trees like *Casuarina* for fuel and the accumulation of larger pig herds (Gagne 1980:154). It is clear that humans have greatly altered the natural landscape in Papua New Guinea, through their widespread use of fire and agriculture.
CHAPTER FOUR

CONCLUSIONS

This thesis set out to present an overview of the two major theories concerning the origins of agriculture in Papua New Guinea. The two theories do not in fact occur concurrently; it appears that there was an early view, which eventually changed into the more recent theory, after extensive archaeological research. The thesis presented the evidence for both of the theories, to show how the original view became discounted by the more recent theory. Evidence now strongly indicates that Papua New Guinea was in fact an early centre for the independent development of agriculture, in the terminal Pleistocene / Holocene period (10,000-9000 BP).

In summary, it was originally thought that the concept of agriculture only arrived in Papua New Guinea with the Austronesians some time in the Mid-Holocene, after a transfer out of Southeast Asia. It was also thought that many of Papua New Guinea's main cultigens of Southeast Asian origin only arrived at this time, as well. There does appear to be a number of archaeological sites with agricultural features (anthropogenic grasslands and agricultural tools), in the Papua New Guinea Highlands, that date to around the Mid-Holocene, lending support to the theory that agriculture only arose at this time. Many of these sites indicate that humans were exploiting and modifying their environments around the Mid-Holocene, through the practices of burning and tree-felling, in preparation for cultivation. This fact alone tended to support the theory that it was at this time that agriculture first began. However, it has since been shown that many agricultural artefacts or tools, (particularly wooden tools), are rarely preserved longer than 5000 years, which could create a bias for the original
theory. This early theory was likely to have developed some time in the 1960s or earlier, prior to the extensive archaeological investigations that have since been undertaken in the Highlands of Papua New Guinea. This early view seems somewhat imperialistic, in that it was assumed that agriculture in Papua New Guinea had to have come from somewhere else. It was not until the early-mid 1970s that questions arose concerning the possibility that Papua New Guinea could in fact represent an independent centre of early agriculture. Despite evidence that dated to the Early Holocene, this second theory was not entirely embraced for a number of years; no doubt pending further archaeological investigations.

Despite the fact that only a small number of sites of a sufficiently early age directly support the theory that Papua New Guinea developed agriculture independently of Southeast Asia, the evidence from two of these sites is fairly conclusive. The evidence is extremely convincing at the swamp garden site of Kuk, as the ditches and channels that date to around 9000 BP, provide some of the best examples of some of the earliest drainage systems in the world. The fact that there are many archaeological sites in Papua New Guinea with agricultural features that date to the Mid-Holocene, indicates that the Austronesians may well have expanded into Papua New Guinea with their domesticated plants, animals and other agricultural features at this time. This does not discount the fact that there was a horticultural base already established in Papua New Guinea to some extent. The early horticultural experiments and cultivations within Papua New Guinea likely consisted of a combination of indigenous plants (Pandanus nuts, sugarcane, and Australimusa bananas), and introduced plants (taro and yams). The transfer of the Austronesian influences may well have reinforced any horticultural experiments that had already taken place within Papua New Guinea.
The question of the antiquity of pigs in Papua New Guinea is awaiting further research, as it could provide more evidence to either support or discount the theory that Papua New Guinea developed agriculture independently of Southeast Asian influences. At this time, there is limited evidence of the presence of pigs in Papua New Guinea around the terminal Pleistocene / Holocene period, which indicates that pigs may not have been introduced into Papua New Guinea with Southeast Asian agriculture, as it has been suggested.

It appears that the transfers of Southeast Asian cultigens and agricultural technology in the Mid-Holocene had little to do with the origins of agriculture in Papua New Guinea. The earliest date in Papua New Guinea associated with agriculture is currently c.9000 BP for what are assumed to be taro gardens at the Kuk site in the Highlands. This date compares favourably with many dates for incipient agriculture in East and Southeast Asia. It is now believed that humans in Papua New Guinea were actively manipulating their environments in the Late Pleistocene, which is much earlier than was originally thought. It is possible that humans were practising small-scale cultivation prior to this 9000 BP date. It has since been shown that taro and yams have been in Papua New Guinea for at least 9000-8500 years and possibly even 10,000 years. If the Kuk swamp gardens represent a functioning irrigation system at 9000 BP, then incipient agriculture could prove to be quite a bit older in Papua New Guinea. As noted, taro has been claimed as the crop under cultivation in the Kuk swamp, with yams as the dryland counterpart. Taro has not been officially identified as a species native to Papua New Guinea, and although it was previously thought to have been native to Southeast Asia, its true origin still remains unknown. Nowhere in Southeast Asia have taro gardens been found in the archaeological record, to the extent that they have in the Early Holocene sites in Papua New Guinea. Perhaps the environmental conditions in Southeast Asia were not as suitable as they were in Papua New Guinea, at the beginning of the Holocene,
and so taro did not become as important as other cultigens, such as rice. It is still not exactly known why taro was so suitable for wetland gardens in the Papua New Guinea Highlands, and yet has not been found in Southeast Asia in such antiquity. There is no doubt that increased archaeological investigations would probably shed some light on this fact. In the meantime, it does seem likely that Papua New Guinea was in fact an independent centre for early agriculture; that agriculture did not rise only after a transfer out of Southeast Asia.
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