PEOPLES AND PLANTS IN MELANESIAN PREHISTORY

The history of cultivated plants

D.E. YEN

Kuk and the history of agriculture in the New Guinea highlands

JACK GOLSON

Irrigation in Melanesia: formative adaptation and intensification

MATTHEW SPRIGGS
THE HISTORY OF CULTIVATED PLANTS

D.E. Yen

The origins of agriculture and the domestication of plants (and animals) form a generalized equation within the wider frame of world history. However, for Melanesia, a principal prehistoric gateway for human populations in the settlement of Pacific Islands, the origins of agriculture have long been associated with the diffusion of plant species out of southeast Asia. Thus, in most collections of essays on world agricultural origins, the conspicuous role for Oceania as a whole has been its absence.

It is within the last twenty years, that the passive acceptance of this situation in this part of the world has undergone gradual reassessments. Founded on the research of ethnobotanists, human geographers and archaeologists who have turned their attention to detailed studies of indigenous Pacific production systems, basic questions on origins, domestication and diffusion are now being asked. A key area is Melanesia and a major force in re-opening these questions through the provision of data from the wide fields of enquiry has been indeed, the Research School of Pacific Studies.

I would like to begin the discussion of this conversion of attitude in terms of a simple dialectic of uniformity and diversity in considering the adaptation of agriculture in the Pacific:

Uniformity - the presumed Asiatic origin of cultigens that may be identified as the genetic component in the process;

Diversity - the soils and climates to which the adventive plants were adapted - the environmental component.

This sets up a situation of heredity and environmental interactions that are akin to natural selection; the varying ecologies of Melanesia have constituted variable screens through which adventive plants have passed, to result in species dominance. This reflects their individual, specific genetic adaptations. Within the species, selection operates to allow for the expression of individual genes and gene combinations, and mutations, all with qualities adaptive to new and sometimes unique conditions to which species may not have been exposed before. Thus the effect of the interaction between the genetic and environmental factors sets the stage for adaptive diversity.
With the intercession of man as agriculturist however, this natural model of adaptation takes on a more complex configuration, for he it is who adds what used to be called 'nurture' to the nature v. nurture argument of classical genetics in two ways:

Volitively, by modifying the environment in the direction of preference for the principal plants he is cultivating; and

In doing so, less consciously altering the directions of selection that might have resulted from the influence of the natural environment alone.

The directions in which manipulations of the environment have been applied have, therefore, the basic determinism of environment, and this determinism may be defined in terms of stress, such as excessive wetness or dryness, naturally impoverished soils (coralline atoll soils, highly laterized mountain soils); thus the obvious steps of water application (irrigation), restriction (drainage), mulching, the application of organic matter, and perhaps more commonly, combinations of two or more techniques in cultivation. In Melanesia, it may be said that the apogees of such agricultural technology were reached in prehistory, and indeed represent the highest agronomic achievements for the Oceanic world.

The social factors of environment however, such as significant production for ceremonial purposes, population pressures due to increases and group competition, class pressures in stratified societies, or the requirements of commercial market production may require the adoption of intensive techniques, e.g. the conversion of long rotation swidden to short rotation; the accentuating of irrigation. There is perhaps the inference of sequence in the adaptation of agriculture of

(1) Formative adaptation dictated by natural climatic and edaphic factors, and

(2) Intensification, triggered by dynamic social environments.

An alternative stimulus, however, may be the perceived deleterious effect of the initial techniques adopted, as indicated by increasingly inadequate production, with often territorial restriction on extensification of an accustomed mode of production.

Whatever the mode of environmental manipulation by man, he provides the setting for a further intensification, seldom recognized as such - the domestication of useful elements of the wild flora' - to supplement the plant rosters for which the original intensifications were designed. These may not be only food plants, but medicinal, ornamental and ceremonial, and industrial. From the minimal environmental disturbances of hunter-gatherers, through the forms of swidden agriculture, with or without burning, to the more elaborate and intensive forms of production, they provide the opportunities for the controlled reproduction of otherwise spatially wide-ranging species. The success of this control of the breeding system of plants (and animals) is the key to the process of domestication. At the same time, environmental disturbances can often provide the media in which hybridizations within and between species can occur; or in which the agriculturist can favour modes of reproduction in a
species - vegetative v. seed production; selection towards inbreeding (uniformity) or outbreeding (variability).

The more sophisticated forms of agricultural control, like the complex irrigation and drainage systems that are more fully treated by Matthew Spriggs, produce more highly specialized environments, and a trend towards monospecific cropping. In most cases, one genetic result is a large array of varieties of the dominant species grown that are adapted towards such artificial environments.

In this paper, we seek to review the history of the cultivated plants of Melanesia, and from what has gone before, we are to question the total acceptance of agriculture as a product of diffusion, and indeed, separate out the issue of domestication of plants from the origins of agriculture. I will further attempt to demonstrate that genetic selection including domestication is an agricultural intensification which has been a feature of Oceanic agriculture, continuing into the recent past, when the entry of commercialization interrupted, or changed the directions of the processes of agricultural evolution in the Pacific.

MELANESIAN AGRICULTURE AND SOUTHEAST ASIAN PLANTS - THE DOMINANT SPECIES

The indigenous Melanesian agricultures have been characterized as dominated by the field cultivation of Dioscorea yams and Colocasia taros. As staple root crops, vegetatively reproduced, these species show biological characters that are in common, but physiological adaptations that contrast, as Barrau (1965) has called them Dry and Wet, that fit them into the broad environmental variants of the islands. In most agricultural systems, however, it is rare that one crop is present in total absence of the other. Systems situated within 'wet' ecologies (riverine, stream, swamp) tend to exhibit dominance of taro, but usually there is a 'dry' component in which some yam will be cultivated. In tropical rain forest settings, however, taro may dominate the 'dry' or swidden gardens (with the absence of significant water control techniques), while yams are nevertheless adapted by elaboration of agronomy to the 'wet' conditions. The complexity of the genetic environmental relationships may be further demonstrated in the adaptation of these species, where, in the case of taro, agricultural adjustments may include the artificial supplementation of water in the building of water-retaining pondfields, or the 'drying' effects of elevation of planting surfaces in swamps above water in 'island'-like formations. With yams, elaborate soil treatments including mounding of artificially fine soil, the addition of green manure (composting), and deep holeing are variously applied, conferring drainage on the one hand, and textural conditions for roots to reach the deeper moistness for large tuber formation on the other.

If our knowledge of agricultural techniques and their rationales are fragmentary, even more rare are the definitions of origin and adaptation of varieties of any of the species to the varying conditions, natural and artificial.

But to questions of origins of yams and taros:
By cytological analysis, the Colocasia taro is represented by three chromosome-number forms only in India, (Yen and Wheeler 1968), and is confirmation of Vavilov's (1949-50) designation of Indian origin, not only for Colocasia, but for other related genera of Oceanic distribution of the aroid root crops, Alpinia and Amorphophallus. On the mainland of southeast Asia, the Colocasia is found in cultivation, but if fieldwork in Thailand is any indication, wild forms are rare or absent, while the narrow range of plant variation does not indicate proximity to a centre of origin.

Indeed, the Philippines and island southeast Asia exhibit incomparably greater plant variation, and may reflect prehistoric connections with India with contacts putated by Beyer (1948) in the second or third centuries BC for the Philippines; and for Indonesia, somewhat earlier. If wild forms are absent in the western Pacific, a diffusion hypothesis for the taros seems valid enough so far; but the uncertain status of the origin of feral types found in New Guinea, and more recently by R. Jones and B. Meehan (pers. comm.) in inland Arnhem Land, Australia, militate against ready acceptance. It has to be allowed that these feral types may not be garden escapees (and the Arnhem Land representatives would require a more complex explanation), but representatives of the attenuated Malaysian natural flora that is discussed later.

There are two other taros, the American *Xanthosoma* of post-Columbian introduction and found in most dryland agricultural systems as a subsidiary crop, and the swamp taro, *Cyrtosperma chamissonis*, adapted as a staple in the eastern Melanesian islands and most of the atolls of Micronesia. Wild species of *Cyrtosperma* are found pantropically in Africa, Asia, Indonesia, New Guinea and America, but the Pacific cultivated species has a narrower distribution (Barrau 1958), indicating that it is the first example that we encounter of an endemic cultigen that may indeed be a regional domesticate from within the New Guinea-Fiji confines.

The major species of yams, by contrast, are unquestioned concerning their southeast Asian origins; by taxonomic analysis (Burkill 1960), they are the domesticates there within a great range of wild species.

Cytological analysis by Martin and Ortiz (1963) has confirmed the claims of southeast Asia as the centre, in that the greatest range of chromosome numbers (2n = 20-100+) is found there. There do remain, however, the *Dioscorea* species of minor agricultural importance that are often enumerated as 'wild' in southeast Asia and Melanesia -- *D. bulbifera*, *D. hispida*, *D. pentaphylla*. These species may represent the attenuation of the Indo-Malayional flora, long recognized since Wallace (1869), but they are cultivated only in some Melanesian islands. *Dioscorea* supp. (note plural) forms from New Guinea which are not equatable with the known species, are often attributed as 'cultivated' or 'sometimes cultivated' by local groups. The yams of Melanesia have not been studied sufficiently. It is not in the major cultivated species that there are questions, but in the underlying minor representatives of the genus. For example, I have been unable to identify two 'semi-cultivated' forms collected among the Karam by Ralph Bulmer; the cultigen common in coastal villages called *D. nummularia* does not match up with the type specimen held in the National Herbarium of the Philippines, nor with any of the suite of species cultivated in Asia or Oceania.
The full realization that the *Metroxylon* sago palms are cultivated as a staple (e.g. Eyde 1967; Rhoads 1979) has been somewhat obscured by the great tracts of naturally occurring stands, particularly in New Guinea; thus the common characterization of the starch as an objective of plant gathering in lowland areas. The interesting feature of the distribution of sago in Melanesia is its species differentiation (Barrau 1959). In New Guinea, three species are recognized, *M. rumphil*, *M. salomonense* and *M. sagus*, of which the first and last are recognized as having domesticated forms. Barrau (1958:37) noted that cultivated forms of *sagus* and *rumphil* are often spineless in their petioles and leaf spathes in contrast to wild stands that vary in this character. Thus selection is an integral part of the continuing domestication process. Since, however, *M. sagus* is propagated by suckers in preference to seed, the domestic form is, more often than not, a clonal population, whose genetic maintenance does not require great concentration. Other Melanesian forms like *M. salomonense* and *M. vitiense* differ in their reproductive habit, in that they are obligatory seed producers. A notable feature of domestication of these sagoes is their adaptation beyond the normal swamplands to hillside in inland situations where their water requirements must be fulfilled by rainfall. Indeed in many parts of the Solomon Islands, they are good indicators of earlier agricultural activity, while in some cases, the occurrence of naturalized groves may indicate proximity to inland sites of protohistoric and earlier occupation. Selection of *M. salomonense* has produced forms that are preferred for thatch and other leaf uses rather than for food.

Bananas are virtually a universal component of Melanesian gardens, ranging from dominance as a crop in some parts of the southern New Guinea highlands, to village garden features. Although botanically banana is a herb, it reflects an aspect of Melanesian agriculture that is sometimes inadequately accounted for - the perennial, *aboriginal* components of production. Now, the majority of bananas in Oceania are of the Eumusa section of the genus, originating in southeast Asia. The Australimusa section, however, which spread into island Melanesia and eastern Polynesia, has been established by Simmons (1962) as a New Guinea domesticate.

Coconut palms still dominate the landscapes of coastal Melanesia and the Pacific atolls where they are a staff of life. On such restricted edaphic ecologies, they are the best adaptation, not only for food and drink, and medicine, but for wood, fiber (sinnet) and leaf materials used for building and the manufacture of utilitarian and more esoteric artifacts. The origin and domestication of the palm has been an object of debate, since the 'wild' representatives of its botanical family are found on the shores of northwest South America. Although claims for southeast Asian domestication have often been made, the most reasonable and recent hypothesis of Sauer (1971) is that of a multiple Oceanic domestication of volunteer stands, originating from accidental flotation of the fruits. The great range of variation in the Pacific species, and the distinctive local varietal groups of the islands offer some support to this hypothesis. Coconut is a rare example of local domestication that has entered the orbit of commercial agriculture, unchanged until recently by the hand of modern plant breeding.
One of the most important of tree crops in Oceania is the breadfruit, whose origin has been attributed by Burkill (1935) to the Pacific Islands. In Indonesia and in New Guinea, its status in traditional systems has been as a wild and cultivated plant. Its place in agricultural systems is minor. From this centre of variability, the domestication of this tree is seen as a kind of west-to-east cline of increasing agricultural importance, to the outreaches of tropical Polynesia. The other characteristic of this continuous process over space and time is the increasingly intensive selection for seedlessness that was accompanied by the choice of clonal reproduction as a standard procedure in planting.

Sugar cane is nowhere an agricultural dominant in subsistence systems, but is again a universal in tropical Oceanic cultigen rosters. It is considered here, because like the coconut, it has become a Pacific contribution to world commerce. Genetic analysis has placed this species as a New Guinea domesticate (Warner 1962), beyond any reasonable doubt. The continuing evolution of a cultivated species is demonstrated in the populations of sugar canes collected in Fiji. Grassl (1964) reported that atypical clones there were the product of introgression hybridization with Miscanthus; subsequent cytological analyses by Price and Daniels (1968) were to support this hypothesis.

The sweet potato is an American plant, whose introduction, generally accepted as being introduced to Melanesia in post-Columbian times, made such an agricultural impact on agriculture (Yen 1974). Probably more adaptable to the wide range of climate and soils than any other Oceanic plant, it soon dominated the subsistence systems of the highlands of New Guinea. Its increasing adoption in modern times in a wide range of settings was first noted in the Trobriands by Malinowski (1935), and in the western Solomons by Oliver (1955) in the 1920s and 1930s. With the dissolution of many Pacific subsistence systems in pursuit of cash economies, the sweet potato has expanded even more—a testament to its productive capacity, adaptability, and relative to the traditional yam-taro cultivation, lower labour inputs required. American plants have made considerable inroads into traditional agricultural systems, beginning with tobacco, which probably reached the New Guinea highlands as early as sweet potato, the Xanthosoma taro and maize being of unknown introduction dates. Manioc or cassava was adapted into island cropping in the nineteenth century, and, like the sweet potato, for many of the same reasons, is now expanding in the subsistence sector of transitional systems. In this century, development of cash farming in Melanesia has been largely dependent on two further American species, cacao and coffee. It is only very recently that there has been significant diversification of commercial cropping in Melanesia with the successful introduction of the southeast Asian rice and the African oil palm (see Table 1).

MELanesian Plants

From this review of the dominant plants in traditional Melanesian agriculture, two points with regard to origins are patent:
### Table 1

**Origins of the Major Commercial Crops of Melanesia**

<table>
<thead>
<tr>
<th>Names</th>
<th>Modern Improvement in Oceania</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vernacular</td>
<td></td>
</tr>
<tr>
<td>Coconut</td>
<td>Philippines (breeding)</td>
</tr>
<tr>
<td></td>
<td>PNG (hybrids)</td>
</tr>
<tr>
<td></td>
<td>(Sri Lanka)</td>
</tr>
<tr>
<td></td>
<td>Indonesia</td>
</tr>
<tr>
<td>Sugar Cane</td>
<td>Fiji</td>
</tr>
<tr>
<td></td>
<td>Hawaii</td>
</tr>
<tr>
<td></td>
<td>Philippines</td>
</tr>
<tr>
<td>Rice</td>
<td>Japan</td>
</tr>
<tr>
<td></td>
<td>Taiwan</td>
</tr>
<tr>
<td></td>
<td>Philippines</td>
</tr>
<tr>
<td></td>
<td>Indonesia</td>
</tr>
<tr>
<td>Cocoa</td>
<td>America</td>
</tr>
<tr>
<td>Coffee</td>
<td>America</td>
</tr>
<tr>
<td>Chili pepper</td>
<td>America</td>
</tr>
<tr>
<td>Rubber</td>
<td>America</td>
</tr>
<tr>
<td>Oil Palm</td>
<td>America</td>
</tr>
<tr>
<td>Pyrethrum</td>
<td>Africa</td>
</tr>
<tr>
<td>Ginger</td>
<td>India</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(1) The central role of New Guinea in domestication of plants: those now definitely assigned; those which could be domesticated there.

(2) That these domesticates as a whole, virtually cover the range of environmental adaptations within Melanesia. And it is notable that among these a number of them were staple domesticate species for swamp, coral islands, coastal, inland and mountain environments.

Tables 2 and 3, demonstrating these adaptations, are compiled with the assistance of the recent comprehensive ethnobotanical enumerations for New Guinea by Powell (1976), for Malaysia by Burkill (1935) and for Indonesia by Ochse and Bakhuizen v.d. Brink (1931).

Since the determinations of New Guinea origins for sugar and Australimusa banana, there have been further examples noted of endemic cultigens, that by their very exclusiveness, or limited dispersal and the existence of wild forms, cannot be denied. These, including the now well-known vegetable plants of the highlands, are incorporated in Table 3.

Recent studies in the Solomon Islands have indicated that indigenous intensification or technological change was not in crop agronomy intensification (control of environment), but in a genetic direction of selection in trees, fruit and nut producers (Yen 1974b). One result has been the gigantism of plant parts consumable as food. A further example has been domestication of some tree species. The primary example that is the subject of further research is the Canarium nut of the species *harveyi* var. *nova-hebridensis*. This species, one of the largest, if not the largest fruited *Canarium* over the southeast Asian, Chinese (South) and western tropical Pacific distribution of the genus, is limited to the eastern Solomon Islands and the Banks Islands. The interpretation of this distribution is that domestication occurred after any role the eastern Solomon Islands may have had in the prehistoric movements of populations towards nuclear Polynesia and eastwards. It should be noted that this area is the centre of distribution of Lapita sites (Green 1976), of considerable importance in considering human dispersals in Polynesian prehistory. Further, the established domesticates such as taro, yam, breadfruit, etc., are shared throughout Melanesia and Polynesia, and are regarded as the accompaniments of the spread of human populations in the Pacific.

As may be seen from Tables 2 and 3, the selective emphasis on the putatively Melanesian domesticates has been somewhat towards the vegetative mode of reproduction, where facultative seed production was a biological alternative. The *Canarium* example, like coconut and some of the sago palms, did not present the clonal option. It is an interesting example of the influence of the effect of variability due to the outcrossing breeding system on plant varietal naming. On the island of Santa Cruz, there are names for *Canarium*, largely descriptive of variable nut characters. However, on the testing of seven informants, the consistency of naming of eight trees was so poor that coincidences could be assigned to chance, there being a total of nineteen names given. On Vanikoro, another eastern Solomon Island, there is no effort given to naming of *Canarium*, in contrast to yam, taro and even sweet potato varieties (all clonal and thus true breeding).
## Table 2

### The Traditional Staple Plants of Melanesia

<table>
<thead>
<tr>
<th>Vernacular</th>
<th>Botanical</th>
<th>Origin</th>
<th>Adaptation</th>
<th>Reproduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taro</td>
<td><em>Colocasia esculenta</em></td>
<td>As</td>
<td>Swamp/Riverine Mountain</td>
<td>Clonal</td>
</tr>
<tr>
<td>Yam</td>
<td><em>Dioscorea alta</em></td>
<td>As</td>
<td>Coast/Mountain</td>
<td>Clonal</td>
</tr>
<tr>
<td></td>
<td>&quot; esculenta*</td>
<td>As</td>
<td>Coast</td>
<td>Clonal</td>
</tr>
<tr>
<td></td>
<td>&quot; bulbifera*</td>
<td>As</td>
<td>Coast/Mountain</td>
<td>Clonal</td>
</tr>
<tr>
<td></td>
<td>&quot; pentaphylla*</td>
<td>As</td>
<td>Coast/Mountain</td>
<td>Clonal</td>
</tr>
<tr>
<td></td>
<td><em>Dioscorea</em> spp.</td>
<td>M(NG)</td>
<td>Coast/Mountain</td>
<td>Clonal</td>
</tr>
<tr>
<td>Banana</td>
<td><em>Musa</em> section Eumusa &quot; Australimusa*</td>
<td>As</td>
<td>Coast/Mountain</td>
<td>Clonal</td>
</tr>
<tr>
<td></td>
<td>&quot; M(NG)</td>
<td>M(NG)</td>
<td>Coast/Mountain</td>
<td>Clonal</td>
</tr>
<tr>
<td>Sago</td>
<td><em>Metroxylon sagus</em></td>
<td>M(NG)</td>
<td>Swamp/Riverine Mountain</td>
<td>Clonal</td>
</tr>
<tr>
<td></td>
<td>&quot; rumphii*</td>
<td>M(NG)</td>
<td>Swamp/Riverine Mountain</td>
<td>Clonal</td>
</tr>
<tr>
<td></td>
<td>&quot; salomonense*</td>
<td>M</td>
<td>Swamp/Low Montane</td>
<td>Seed</td>
</tr>
<tr>
<td></td>
<td>&quot; vitiense*</td>
<td>M</td>
<td>Swamp/Low Montane</td>
<td>Seed</td>
</tr>
<tr>
<td>Swamp Taro</td>
<td><em>Cyrtosperma chamissonis</em></td>
<td>M(NG)</td>
<td>Swamp/Coastal</td>
<td>Clonal</td>
</tr>
<tr>
<td>Breadfruit</td>
<td><em>Artocarpus altilis</em></td>
<td>M(NG)</td>
<td>Coastal/Low Montane</td>
<td>Clonal</td>
</tr>
<tr>
<td>Coconut</td>
<td><em>Cocos nucifera</em></td>
<td>O</td>
<td>Coastal</td>
<td>Seed</td>
</tr>
<tr>
<td>Sweet potato</td>
<td><em>Ipomoea batatas</em></td>
<td>Am</td>
<td>Coastal/Montane</td>
<td>Clonal</td>
</tr>
<tr>
<td>Manioc/Cassava</td>
<td><em>Manihot esculenta</em></td>
<td>Am</td>
<td>Coastal/Low Montane</td>
<td>Clonal</td>
</tr>
<tr>
<td>Vernacular</td>
<td>Botanical</td>
<td>Origin</td>
<td>Adaptation</td>
<td>Reproduction</td>
</tr>
<tr>
<td>---------------------</td>
<td>-------------------------------</td>
<td>--------</td>
<td>---------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Pueraria lobata+</td>
<td>As</td>
<td></td>
<td>Coastal/Montane</td>
<td>Clonal</td>
</tr>
<tr>
<td>Dryland taro</td>
<td>Alocasia spp.+</td>
<td>As</td>
<td>Coastal/Montane</td>
<td>Clonal</td>
</tr>
<tr>
<td>Tobacco</td>
<td>Nicotiana tabacum</td>
<td>Am</td>
<td>Coastal/Montane</td>
<td>Seed/Clonal</td>
</tr>
<tr>
<td>Screwpine</td>
<td>Pandanus odoratissimum</td>
<td>O</td>
<td>Coastal</td>
<td>Clonal</td>
</tr>
<tr>
<td></td>
<td>&quot; julianettii +</td>
<td></td>
<td>Montane</td>
<td>Clonal</td>
</tr>
<tr>
<td></td>
<td>&quot; brostmos +</td>
<td></td>
<td>Montane</td>
<td>Clonal</td>
</tr>
<tr>
<td></td>
<td>&quot; conoides</td>
<td>M</td>
<td>Coastal/Low Montane</td>
<td>Clonal</td>
</tr>
<tr>
<td></td>
<td>&quot; dubius</td>
<td>M</td>
<td>Coastal</td>
<td>Clonal</td>
</tr>
<tr>
<td>American Taro</td>
<td>Xanthosoma sp.</td>
<td>Am</td>
<td>Coastal/Low Montane</td>
<td>Clonal</td>
</tr>
<tr>
<td>Ti plant</td>
<td>Cordyline fruticosa+</td>
<td>M(NG)</td>
<td>Coastal/Montane</td>
<td>Clonal</td>
</tr>
<tr>
<td>Barringtonia</td>
<td>Barringtonia procera+</td>
<td>M</td>
<td>Coastal/Low Montane</td>
<td>Clonal</td>
</tr>
<tr>
<td></td>
<td>&quot; novae-hiberniae</td>
<td>M</td>
<td>Coastal/Low Montane</td>
<td>Clonal</td>
</tr>
<tr>
<td>Papaya</td>
<td>Carica papaya</td>
<td>AM</td>
<td>Coastal/Montane</td>
<td>Seed</td>
</tr>
<tr>
<td>Sugar Cane</td>
<td>Saccharum officinarum</td>
<td>M(NG)</td>
<td>Coastal/Montane</td>
<td>Clonal</td>
</tr>
<tr>
<td></td>
<td>&quot; edule</td>
<td>M(NG)</td>
<td>Coastal/Montane</td>
<td>Clonal</td>
</tr>
<tr>
<td></td>
<td>&quot; Setaria palmifolia</td>
<td>M(NG)</td>
<td>Montane</td>
<td>Clonal</td>
</tr>
<tr>
<td></td>
<td>&quot; Rangia klossii</td>
<td>M(NG)</td>
<td>Montane</td>
<td></td>
</tr>
<tr>
<td>Winged bean</td>
<td>Psophocarpus tetragonolobus</td>
<td>M(NG)</td>
<td>Montane/Low Montane</td>
<td>Seed</td>
</tr>
<tr>
<td>(vegetable)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oceanic Lichee</td>
<td>Pometia pinnata</td>
<td>M</td>
<td>Coastal/Low Montane</td>
<td>Seed</td>
</tr>
<tr>
<td>Nali nut (eastern</td>
<td>Canarium harveyi var+</td>
<td>M</td>
<td>Coastal</td>
<td>Seed</td>
</tr>
<tr>
<td>Solomons)</td>
<td>nova-hebridiense</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As = Asian
Am = American
M = Melanesia
O = Oceanic (including Melanesia)
M(NG) = specifically New Guinea
? = possibly domesticated in Oceania
* = Present status of 'supplementary'
+ = Potentially of 'main' or staple status in the past
THE HISTORY OF CULTIVATED PLANTS

The *Canarium* of the eastern Solomons represents then, an eastern extension of the domestication process that we recognize in New Guinea. In the Pacific, however, this is not the ultimate extent of the process (Yen in press). Among other domesticates are the *Pandanus* spp. developed from naturally occurring species of narrow range on atolls of Polynesia and Micronesia (Stone 1963), the purposeful planting of *Sporus* reed on Easter Island gardens, the cultivation of an endemic genus *Touhardia* (Urticaceae) in Hawaii (Kamakau 1976:44-45) – and there are questions of the wild status of a range of New Zealand plants at contact – *Phormium* flax; the karaka berry (*Corynocarpus*); *Cordyline australis*, the cabbage tree.

Oceania, as the attenuation of the distribution of the Malaysian or Indo-Malaysian flora, and as the recipient of human populations from southeast Asia, presents a situation of extended opportunities in the past for further, remote domestication of new ecotypes. Particularly is this so if the human component were horticulturally/agriculturally based; in other words, with the expected diffusion of agricultural ideas with agricultural plants.

We have thus arrived, in a circular way, back to the diffusion hypothesis, by isolating consideration of Pacific domestication of plants from the issue of agricultural origins.

THE ORIGINS OF MELANESIAN AGRICULTURE

At this juncture, I would like to state the alternative hypothesis, poorly disguised, I think, in what has preceded: that agriculture independently evolved in Melanesia, specifically in New Guinea. A suite of plants was domesticated that included basic staples, vegetable and fruit species that were able to sustain human populations in their settlement of diverse and foreign ecologies from beginnings of hunting and gathering, and was a continuing process. However, this continuity was interrupted by further colonists out of Asia this time with agriculture and transferred domesticates, which were to dominate, in many cases, the earlier evolved cultivation of indigenous domesticates: these to become secondary, in Barrau's phrase (1965), 'witnesses of the past'. The prehistorical correlates for such an hypothesis are well-known; the settlement of the Sahul continent by hunter-gatherers from 40-30,000 years ago, and the implied endogenous succession or evolution to agriculture in the northern part; and the arrival of the agricultural Austronesians at 4000 BC.

In the face of the traditional hypothesis, this alternative, rarely considered, would remain as such, were it not for the work of Jack Golson (Golson 1977 and in press; Golson and Hughes in press) in the Wahgi Valley. Most of you are familiar with the interrupted sequence of agriculturally associated drainage systems that date back 9,000 years. At this antiquity, the timing, at a period of ameliorating climate corresponding with rising sea levels and the major division of the Sahul continent, could be said to be fortuitous for a significant development in production modes at former marginal (and beyond) environments. Such a development could be the domestication of useful parts of a hunting-gathering flora. It will be noted that I have been careful to term this 'development' rather than 'origin'. The source of this caution is that the process of domestication may have begun, and would have been a
more logical sequence of events, earlier than drainage manipulation of the environment. As we have already inferred, drainage means the tailoring of one particular feature of the environment to the requirements of a species or suite of species. Thus, domestication may have begun in the variable ecologies of mid-altitude regions, to develop simpler regimes of swidden modes of agriculture that followed the long hunter-gatherer 'phase' in Papua New Guinea.

I hope that I do no violence to the interpretations of Golson in converting his data to my own conceptual ends, in what follows.

The evolutionary nature of the drainage systems

The increasing complexity of these systems of environmental management through time appears as an evolutionary sequence of intensification of production mode, in addition to successive methods of coping with a naturally marginal but dynamic medium for agriculture. Recognizable is increasing 'specialization of environment' signalling the earlier accommodation of taro as a crop, and later, the American sweet potato. The major question regarding the earliest part of the sequence is: from whence is it derived? A local endogenous development born of increasing ethnobiological knowledge translated into methods of environmental control? A result of diffusion of ideas (and crops) and from where? In our southeast Asian work, we are still grappling with the controversy of agriculture v. non-agriculture in the late manifestations of the Hoabinhian technocomplex.

The evidence for plant domestication in New Guinea, and the overview of the evidence for New Guinea man's manipulation of the environment endues that continental island with the possibility of the application of the classical model of hunting-and-gathering to agriculture by internal development. But having built this case on plant origins, and having used Golson's researches in a summary way where they fit, it is only fair to transmit to you something of our continuing dialogues on two further points of interpretation.

The early place of taro in the sequence

One current opinion is that taro was the vehicle on which drainage development occurred in the highlands. Elsewhere, I have ventured the opinion that the soil imprints in the early phases could represent the traces of domestication, or, more safely, the early cultivation of highland domesticates, e.g. Australimusa banana, Saccharum, Setaria, etc. - an agriculturally formative period.

The general wisdom is that taro (with yam) came into the Pacific with Austronesian speakers at c. 4000 BC (Pawley and Green 1975). The discrepancy with the Wani interpretation is obvious, but if direct evidence can be obtained for taro (e.g. pollen) at early levels, this wisdom may need revision in its agricultural aspect.
The place of pigs in the sequence

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 years ago. The agricultural connection is, of course, that pigs (not indigenous to New Guinea) form an inevitable association with plant husbandry. I am inclined to agree.

CONCLUSION

If the evidence for taro and pig at early time levels in New Guinea (or indeed, Melanesia) can be affirmed in the expanding archaeological record, where does it leave the alternate hypothesis for endogenous agricultural development? Exploded, probably.

But out of the ashes would arise the southeast Asian phoenix. Melanesia, and specifically, New Guinea would be responsible for the impetus to rewrite the agricultural section of southeast Asian prehistory, to tighten the ring of diffusion around the necks of recalcitrants like myself.

To partially salvage the shattered pieces of an unimpeccably based hypothesis, the distinction of survival goes to the second element in this treatment of cultivated plants in Melanesia:

That domestication was a form of genetic-environmental manipulation that continued in prehistory as an alternative mode of intensification - a part of the agricultural template that was to reach the far corners of the Pacific.

In prehistorical studies of cultivated plants, we have gone beyond observations of the diversity of environmental screening of founder plant species - and begin to see something of the biological inventiveness of Pacific man.

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KUK AND THE HISTORY OF AGRICULTURE IN THE NEW GUINEA HIGHLANDS

Jack Golson

This contribution is in the nature of an extended commentary on what Yen's article has had to say about the implications for issues in the history of Oceanic agriculture of the 9,000 years-old agricultural sequence investigated over the last decade in the swamps of Kuk Agricultural (formerly Tea) Research Station at 1,550 m in the upper Wahgi valley near Mount Hagen. I refer the reader to a number of publications which supply details of the Kuk investigations, including changing emphases in their interpretation as the gathering of data and the thinking about them have progressed: Golson and Hughes 1976; Golson 1977, 1981a, b, 1982. Here I wish to take up two particular questions within the framework which Yen's paper has established: the origins of agriculture in New Guinea, and the processes of agricultural intensification in highlands agriculture to which much attention has been paid in interpretations of the Kuk evidence to date.

THE BEGINNINGS OF AGRICULTURE IN NEW GUINEA: WHAT, WHEN AND WHERE

Yen discusses the possibility that the origins of agriculture in New Guinea were independent of the Southeast Asian plants which form an important component of agricultural systems there today. He points to the central contribution which plants indigenous and sometimes endemic to New Guinea have made to the Oceanic suite of agricultural crops. He emphasizes the environmental range represented by these domesticates and their inclusion of basic energy-supplying staples, vegetables, fruits and nuts able to sustain human populations over that environmental range.

I

The relevance of the Kuk investigations to this issue is that they have produced evidence for agricultural operations 9,000 years ago, substantially earlier than the first firm indications of agriculture in Southeast Asia (on which see Yen 1977; Gorman 1977). They have not been illuminating on the question of what plants were being grown in the dry-land and wet-land environments under early agricultural management of Kuk. Nor could it have been otherwise, given the absence of remains of the appropriate plants and the nature of the evidence on which the presence of agricultural activity itself is argued (Golson and Hughes 1976). This evidence falls into two categories: one, the nature of the sedimentary record at Kuk, specifically the interpretation of the onset of accelerated
deposition in the swamp basin at 9,000 years ago was due to accelerated erosion in the dry-land catchments of the swamp resulting from the beginnings of forest disturbance by shifting agriculture; and second, the contemporary presence of cut-and-fill features in the swamp basin itself thought to be more consistent with human activities by way of drainage and cultivation than natural processes of stream action and water scouring.

Yen asked us some years ago to consider the possibility that the imprints in the 9,000 year-old horizon in the Kuk deposits were due to cultivation of New Guinea plants. At the time, however, we were attracted to the proposition that already we were in the presence of Southeast Asian domesticates, including, indeed especially, the water-tolerant taro, then accepted without question as a foreigner on the New Guinea scene. The reason for this, despite the large questions it raised for the history of cultivation in Southeast Asia, as Yen has reminded us again in his paper, was the recent claim by Susan Bulmer (1975:18-19, 36) for the presence of a pig tooth in a 10,000 year-old level in a highlands rock shelter. The argument was that the pig is not an animal native to New Guinea, that it is hardly likely to have made its independent way across the water barriers of eastern Indonesia, that it therefore probably came into New Guinea as a husbanded animal and that, such is the nexus between pigs and agriculture in traditional New Guinea and Oceanic systems, its appearance implies the simultaneous arrival of Southeast Asian cultivated plants.

Each link in this chain of reasoning required substantiation. A matter of particular debate became why, if pigs were in central New Guinea 10,000 years ago, they had not reached Australia before the rise in world sea levels caused by the melting of Pleistocene polar and high mountain ice sheets finally separated New Guinea and Australia at Torres Strait probably between 6,500 and 8,000 years ago (Jennings 1972:37). Consideration of this issue involved questions about the behaviour of pigs under husbandry and in the wild and an appreciation that in conditions of bush-edge farming, as well documented for the pioneering era in Australia (Pullar 1953), pigs are well adapted livestock, able to forage for themselves, and if restrained by a little regular hand-feeding, do not readily go feral. For New Guinea Ralph Bulmer (1968:304, 313) has argued that the preferred habitats of feral pigs are forest edge, disturbed forest and mixed ecological zones containing grasslands, gardens and some secondary bush, all environments associated with agricultural man. Morren (1979:6-7) has recently challenged Bulmer's generalization by pointing out that amongst the Miyannin of the West Sepik Province living between 600 m and 900 m feral pigs inhabit primary and old secondary forest during the seven drier months of the year, when they feed off the fallen fruits of certain trees. Even so, the pigs congregate around Miyannin gardens and settlements for the remaining five months. In other words, it could be argued that the closeness of the relationship of pigs with people is sufficient to explain why pigs belonging to early bush gardeners in the New Guinea highlands did not reach Australia before the water barriers formed.

It may be that the argument will prove to be unnecessary after all. The claim for early pig remains precisely that and has not been confirmed by the published evidence of other excavated sites, of which there are admittedly very few. Kuk itself, a specialized site of drainage and gardening, has produced no bones of any kind. What it does contain, _inter alia_, in its 9,000 year-old levels, is a number of shallow basins, which,
under the influence of Sue Bulmer's report of early pig, I interpreted as fossilized pig wallows (Golson and Hughes 1976). If I do not press this interpretation as much today, it is not because it is an unlikely explanation of the features in question - our observations of pigs wallowing at Kuk today clearly show the contrary - but that there are other possible explanations. There are similar basins in the 6,000 year-old level at Kuk which are more likely to have been made by pigs: in contrast to the earlier hollows, these are associated with stakeholes; the interpretation here, proffered by our workmen immediately the first one was discovered, is that a pig had been secured to a stake at that spot. About 6,000 years ago, moreover, pig bones are reported for a number of highlands rockshelters (Bulmer 1975:19). There are also gardening systems of the same age in the Kuk swamp which possess features interpreted as indicating that taro was one of the crops grown there (Golson 1977:616). Is all this support for 'the general wisdom' of which Yen speaks, that the Southeast Asian elements in New Guinea husbandry came with the arrival of Austronesian speakers in the Pacific? Wurm (Wurm et al. 1975:318319) recognizes the term for pig in a number of New Guinea highlands languages as an Austronesian loan word.

II

In his paper Yen suggests, on theoretical grounds, that the manipulation of the environment by drainage evident in the earliest agricultural levels at Kuk presupposes an earlier stage that saw the development in the variable ecologies of mid-altitude regions of simpler regimes of swidden modes of agriculture. The timing of the agricultural beginnings at Kuk also recommends that we look downhill for their origins.

The researches of biogeographers and geomorphologists over the last two decades have established in broad outline the major climatic and ecological changes that have affected the New Guinea highlands during the past 30,000 years (Bowler et al. 1976:361-366, 388-390; Hope and Hope 1976; Hope 1980; Hope in press, on which last this paragraph is based). In the colder climates of the first 20,000 years of this timespan glaciers formed on the highest mountain peaks and the treeline was depressed by from 400 m and less to about 1,700 m below its present level of 3,900-4,000 m, depending on fluctuations in the temperature. Though the effects below this on the composition of the forest do not seem to have been very marked, beech (Nothofagus) appears to have been widespread between 1,500 m and 2,100 m, indicating persistent cloudiness and mist. The most extreme climate was experienced between 20,000 and 15,000 years ago, after which the temperature gradually rose, bringing a complex suite of changes in its train, including the freeing of the main highlands valleys from their prevalent cloud and mist and the consequent diversification of the regional forest. Climates similar to the present had become established in montane areas by 9,500 BP. The beginnings of agriculture follow so closely on this that, given the fact that the crops which are candidates for planting in the early gardens, whether of New Guinea or Southeast Asian origin, are today almost all within 600 m or so of the ceiling on their productive growth at Kuk, it is hard to believe that they had been established for any length of time anywhere in montane New Guinea. The implication is that agriculture came into the highlands from lower altitudes in step with rising temperatures and the elevation of daily cloud formation.
Recent work by Garrett-Jones (1979) on the sediments of Lake Wanum in the lower Markham valley has provided the first vegetation history anywhere in lowland New Guinea and some of the changes he sees there he is inclined to ascribe to disturbance by man. The first indications, spanning a period of some hundreds of years around 8,000 years ago, consist of increased values for woody non-forest pollen associated with an increased influx of carbonized particles, which result from fire in dry-land vegetation in the vicinity of the lake. As this period is supposed to be more humid than the preceding millennium during which no such evidence of burning is found, Garrett-Jones' conclusion (1979:279-280) is that the agency is likely to be human. Immediately following this episode of vegetation disturbance is the first peak of inorganic sedimentation in the deposits (Garrett-Jones 1979:246). Although consistent with agricultural practice, the evidence is equally consistent with the use of fire as a management strategy for plants and animals by hunter-gatherers (cf. for Australian Aborigines, Jones 1975:25-28). We may simply note the occurrence in these early levels of the Wanum sediments of two pollen grains tentatively identified as *Colocasia*, the genus to which taro belongs (Garrett-Jones 1979:386).

INTENSIFICATION IN HIGHLANDS AGRICULTURE: HOW AND WHY

I

The story reconstructed from the swamp deposits at Kuk is one of continuous agricultural use of dry land from 9,000 years ago, associated with episodes of drainage of the swamp for purposes of cultivation. The emphasis of the investigations has inevitably been on the episodes of swamp drainage, since in contrast to the dry land the swamp is an environment where agricultural operations require the digging of archaeologically discoverable channels and ditches, which are differently spaced through the accumulating deposits according to their varying antiquity.

Six phases of swamp drainage have been defined and are tabulated below, with their (rounded-off) radiocarbon dates Before Present:

<table>
<thead>
<tr>
<th>Phase</th>
<th>Date</th>
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<tbody>
<tr>
<td>6</td>
<td>250-100</td>
</tr>
<tr>
<td>5</td>
<td>400-250</td>
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<tr>
<td>4</td>
<td>2,000-1,200</td>
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<tr>
<td>3</td>
<td>4,000-2,500</td>
</tr>
<tr>
<td>2</td>
<td>6,000-5,500</td>
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<tr>
<td>1</td>
<td>9,000</td>
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Each phase has its own special characteristics, but it is possible to generalize (Golson 1981b; 1982). During phases 1-3 the drainage works necessary to make the wet land fit for gardening consist of a single major disposal channel, while the gardening features themselves are quite varied and have been interpreted as indicating the simultaneous planting of different crops. During phases 4-6 the drainage works are more elaborate,
as though the wet land had become progressively more difficult to manage, while they are also more coordinated, as though it was necessary to have a larger area within the system at one time. The garden structures now consist of a repetitive pattern of straight ditches joining at right-angles, which are thought to mean the cultivation of a single crop, for which taro is proposed for phases 4 and 5 and sweet potato for phase 6. It is not difficult to view this distinction, between phases 1-3 on the one hand and phases 4-6 on the other, in terms of Yen's 'inference of sequence in the adaptation of agriculture: formative adaptation dictated by natural climatic and edaphic factors, followed by intensification triggered by dynamic social environments'.

It is important to appreciate the dialectical relationship which exists between the various elements involved in the sequence. As this relationship is seen in reconstructions from the Kuk evidence for the highlands generally, the continued practice of agriculture modifies the environment in ways which progressively alter the balance between the various elements making up the subsistence system and throw increasing emphasis on the agricultural sector. The path which the environmental modification follows calls repeatedly for developments in agricultural technology and determines the form which agricultural intensification takes as the demands on agricultural production increase. This increasing demand is due both to the disappearance of other resources as the environment becomes transformed and to the proliferation of social needs discovered in the course of that transformation and developed as a result of opportunities presented by it.

These processes are at work over millennia of highlands' history in virtual isolation, given the separation of the montane populations from the lowlands valleys and coasts by steep, climatically unfavourable and thinly inhabited mountain flanks. Perhaps the most important external inputs were new plants. Yen suggests that plants out of Southeast Asia like taro, particular species of yam and some types of banana may be arrivals after the agricultural process got independently under way in New Guinea, as we have discussed. I have pointed to some archaeological evidence that might support such an arrival, together with the pig, by about 6,000 years ago. But the evidence for neither the event nor its effects is clear. On the other hand, we are learning to recognize in the record the consequences of the introduction, within the last few hundred years, of the tropical American sweet potato, which is the current staple of New Guinea highlands economies (Golson 1982).

Let us briefly particularize the generalizations made above: the details are set out and fully referenced in Golson 1981a, b, 1982.

1. The open landscapes of garden, grassland and managed regrowth which are characteristic of the New Guinea highlands today have been created out of environments which palynological research shows were once forested. Since climatic factors have been of minor importance since the end of the Pleistocene 10,000 years ago, it is generally accepted that the agency of this transformation has been man by way of clearance for agriculture. The effects of this clearance, reflected in the depressed ratio of forest to woody non-forest taxa in upper Wahgi pollen diagrams, were so marked by 5,000 years ago that they have been described (Flenley 1979:122) as providing the most striking pollen evidence of recent years for early
clearance, speaking on a pan-tropical or even world scale. Amongst the factors responsible for this degree of impact, two are relevant at this point. The climatic and vegetative evidence reviewed earlier in this paper shows that clearance for agriculture was beginning in the upper Wahgi valley at a time of ecological change at the end of the Pleistocene and it may be that in these circumstances the forest was particularly sensitive to disturbance. In addition to this, certain characteristics of forest growth at altitude suggest that New Guinea highlands forests were at all times slow to recover once disturbed. The primary factors are lowered temperatures and diminished amounts of photosynthetically active radiation, which decrease stature, biomass and productivity (Grubb 1977:102-103).

2. This vulnerability of the montane forest to disturbance was compounded by the fact that because disturbance was due to agriculture, it was repeated. Shifting agriculture of the kind common throughout the tropics, which is inferred for the early stages of highlands New Guinea agriculture, depends for its performance on the regeneration of the forest on the abandoned gardens which have been created by its clearance. Such regeneration reestablishes the nutrient store which has been used up, and rehabilitates the structure of the soil which has deteriorated, under previous cultivation. Since, as we have seen, regrowth of montane forest is retarded by the effects of altitude, early agriculturalists in highland New Guinea must have had to make extensive use of country to allow regeneration to proceed. However, such extensification of agriculture, to use Yen's term, was a finite option in the New Guinea highlands, since the productive growth of tropical cultigens was largely confined within an altitudinally and therefore, because of the topography, laterally restricted zone, with limits set above by cold and cloud (at about 2,000 m before the sweet potato) and below (at about 1,400 m) by climatic and environmental disabilities of various kinds (cf. Brookfield 1964). These limits once reached, the agricultural process was turned inwards and repeated clearing of the same land at shorter intervals would have upset the orderly succession of forest regeneration on which the agricultural system depended.

It is the results of this process which are picked up when the upper Wahgi pollen diagrams to which we have referred begin about 5,000 years ago, and they chart increasing environmental impact for a further thousand years. At this point the archaeological and palaeobotanical record registers a number of developments which have been interpreted (Golson 1981b:60; 1982) as reflections of and responses to the problems posed to the agricultural system by the environmental changes for which its own operations had been responsible. Amongst such developments was the large-scale and long-lived reclamation of land for cultivation represented by phase 3 at the Kuk swamp. The upper Wahgi pollen evidence suggests that this and other reclamations in the region met with a measure of success, allowing some forest regeneration on the valley sides while permitting their continued agricultural use (Golson 1977:621). By 2,500 years ago, however, according to our interpretation of the sedimentary sequence at Kuk, the environmental end-point was being reached in the central valley, with the replacement of degraded secondary growth by grassland. Environmental modification was in the process of becoming environmental transformation, with the most radical of consequences.
3. The montane forests of New Guinea provide plant and animal resources that allowed hunter-gatherers to inhabit the central highlands from early on in the settlement history of the Greater Australian landmass (the earliest published date of New Guinea, of 26,000 BP, is from the Papuan highlands) and are important today in the subsistence of small communities of bush-dwelling gardeners and pigkeepers on the highlands fringes (e.g. Dornstreich 1977; Morren 1977). The progressive alteration of the forest cover brought about by shifting agriculture in the ways described must have had effects on the distribution and availability of those resources in ways about which we can only speculate at present. It is certain, however, that as secondary growth in agriculturally exploited areas became more widespread and more degraded, bush resources became fewer and less varied. Today agricultural communities in such circumstances but with access to the treeline (at around 4,000 m) on the highest New Guinea mountains use it as a favoured area for plant gathering and especially hunting (Hope and Hope 1976: 39-41) and it may be that widespread evidence for treeline disturbance by fire from 5,000 years ago (Hope and Hope 1976: 49-51) is 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 disappeared altogether and were not replaced. The grasslands contain few plants of economic importance, while they only support a limited range of small animals, mainly bandicoots and rats. The hunting of these with fire was one mechanism by which the grasslands once established were maintained.

In these circumstances what was lost in the bush had to be replaced from the gardens. In his paper Yen talks about the agricultural intensification represented by domestication of useful elements of the wild flora to supplement original plant rosters and gives New Guinea examples of the process. The sort of environmental modification of which we have been talking would provide an appropriate context for this to happen. We have no evidence whether this in fact was the case, except very generally for the mountain or nut pandanus. This information comes from the work of the late Ole Christensen at the Manim rockshelter near Mount Hagen. Following the lead given by him (Christensen 1975: 24), we can now say that charred pandanus drupe fragments found there in large numbers in levels older than 6,000 years belong exclusively to a non-domesticated form, the drupe fragments of domesticated trees appearing at a later but as yet unknown date.

In the same way the place of the disappearing forest fauna came to be filled by the domesticated pig. The central importance of the pig in traditional New Guinea highlands societies has its origins in the ecological transformation which made it the only substantial and reliable source of meat. Morren (1977: especially 311-313) has clearly shown the nexus that exists in New Guinea between the degree of environmental impact, the level of pig husbandry and the amount of labour devoted to it. In heavily impacted environments functioning boars are kept in the settlements because there are no feral boars, as elsewhere, with which village sows can be let out to mate. In such environments there is limited opportunity for the animals for forage, so that the expanded herds must be partly maintained on the produce of the gardens and extra labour invested for the purpose. Because pigs have become such expensive animals, their use is subject to strict regulation. They are the currency of important
transactions at every level of community life and as such the substance and symbol of wealth and power.

4. The destruction of the forests and their progressive replacement by increasingly degraded secondary growth and finally by grassland not only make agriculture by far the dominant sector of the economy in the ways described; they call for radical developments within the technology of agriculture itself, since the practices of shifting agriculture are not effective in the changed environment.

The techniques by which highlands farmers achieve successful gardening in grassland have been well described (summarized and referenced in Golson 1977:603-604): the grassland sod is broken up and turned; the soil is tilled and worked into garden beds of various sorts; and seedlings of quickly growing trees are planted or protected on cultivated land going into fallow for extended periods. We think we can recognize these innovations in the archaeological and palaeobotanical record, so that the dates we can give to their appearances become markers for the progress of the environmental transformation which is the key to the developments we are considering. Soil tillage makes its appearance at Kuk 2,500 years ago; tree fallowing may be inferred from the pollen diagrams 1,200 years ago; and raised bed cultivation is being practiced at Kuk 400 years ago (Golson 1981b:60-61, 1982).

In addition, this combination of techniques was able to achieve higher yields, for increased labour inputs, and to allow more continuous cultivation of the same plots of land. With their possession the highlands farmer had the means not only of coping agriculturally with a deforested environment but also of meeting the increased demands which that deforestation placed upon agricultural production.

5. The adoption of the sweet potato into highlands agriculture a few hundred years ago, following its introduction into island Southeast Asia by Iberian explorers of the sixteenth century, was to increase the effectiveness of the measures already taken to meet the problems of agriculture in a montane environment. Its initial attraction for highlands agriculturalists may well have been, as Watson (1977) has argued, that it was unequaled as fodder for pigs, which have a great liking for it and eat it raw. Subsequently, however, its other advantages over the traditional staples of highlands agriculture (Yen 1974:70-74) became manifest, so that it came to dominate in agricultural production for humans as well as for pigs. The sweet potato matures more quickly and gives higher yields at altitude than the older tubers and will do so at higher altitudes; it is more tolerant than they of naturally poor and agriculturally impoverished soils; and its productivity lasts longer than that of taro, and much longer than that of yam, since its shallow rooting allows partial harvesting of individual plants, the roots left behind continue to grow and prolific secondary rooting takes place, with the development of new tubers and the possibility of harvesting for up to two years. Together these factors allowed the sweet potato to effect what Clarke (1977:161) has called a 'spatial and temporal expansion of garden production': spatial through its ability to yield at higher altitudes and on poorer soils, temporal because its tolerance of poorer soils and its longer productivity allow it to perform the role of a follow-up crop in a rotational system.
Elsewhere (Golson 1982) I have assembled the evidence resulting from the actual operation of these factors. It consists of palynological indications of sustained agriculture at 2,500 m; geomorphological evidence of increased rates of sediment deposition in lake basins as a result, it is thought, of intensified land use in their catchments; and a marked contraction of the area of the Kuk swamp under drainage, testifying to a shift in the focus of agricultural activities to dry land. All these developments begin about 2,500 years, which at Kuk is the beginning of phase 6. There is no direct evidence of the effects in the society at large. It is highly probable, however, from what we know of the potential of the sweet potato and the limitations of the crops which it replaced, that gross inequalities in productive capacity under the old regime were to some extent evened out and that it became possible for more people in more areas to undertake pig husbandry and to share in the benefits which ownership of pigs conferred (Golson 1982).

The populous societies unexpectedly met with by the first Europeans to penetrate the highlands fifty years ago were still in dynamic adjustment to the arrival of the sweet potato a few hundred years previously. Their essential character, however, had long been established as a result of the complex interactions between highlands societies and their environment which I have tried to make explicit.

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IRRIGATION IN MELANESIA: FORMATIVE
ADAPTATION AND INTENSIFICATION

Matthew Spriggs

Pour donner une idée de l'industrie de ce peuple, que certaine voyageurs ont dépeint sans religion, sans cultivation aucune, comme vivant dans la sauvagerie la plus profonde, je décrirai la façon vraiment ingénieuse avec laquelle une tarodière est installée sur le flanc d'une montagne ... (Glaumont 1888).

On 19 May 1568 Spaniards of Mendana's ill-fated expedition came upon irrigated gardens while on a reconnaissance on Guadalcanal Island in the Solomons:

On our return we saw many villages up in the hills and many plantations of food on the slopes, arranged very well so that they could irrigate them, which they did. It was well laid out; and by each there was a stream of water (Amherst and Thomson 1907 (II): 306).

This was the first European account of irrigation in Melanesia, a practice which also attracted the attention of Cook and other early European visitors to the region. Many were obviously impressed by the technological sophistication of the irrigation systems, and in their (sometimes grudging) enthusiasm clearly expressed their own feelings of racial and moral superiority. De Rochas, speaking of the Balade area found there,

une sorte de monument de cet art ingénieux, et qu'on est étonné de trouver avec une telle perfection chez un peuple sauvage. C'est un aqueduc de 8 à 10 kilomètres de long, conduit sur la croupe des montagnes, avec un habileté que ferait honneur à un peuple civilisé (1862:170).

Erskine who visited an area thirty miles southeast of Balade, on the river Kalaut observed that,

From all we see it is evident that this part of the country is not generally fertile, but a degree of pains seems to be taken in its cultivation that I never expected to see among savages. The face of the hills above the river is covered with rectangular fields, surrounded by channels of irrigation, which as far as
can be seen from below, is conducted on a careful and scientific system ... (1853:355).

Anderson, again speaking of New Caledonia is slightly more grudging in his praise,

The idea of irrigating the plantations by this means is, perhaps, one which would occur to the most uncivilized savage; but a certain amount of skill displayed in cutting the channels on the side of the hills, which are sometimes wooded, oftentimes rocky, and also in constructing them at a constant, very gradual descent, imperceptible to the naked eye, is sufficient to alter any previously assumed notion that the Melanesian is a know-nothing specimen of the 'genus Homo' (1880:229-230).

Some were sceptical however that the work could have been carried out by Melanesians, for instance Brenchley:

It would appear ... that a more advanced Civilization must have at one time existed on this island. Remains of ancient aqueducts are to be found, one eight miles in length .... It is evident that the skilful irrigation which has so surprised those who saw it, must be a practice that has been transmitted from better times (1873:347).

This was a sentiment echoed by other writers (such as Inglis, 1882:xxii-xxiii), but the Reverend James Copeland on seeing the irrigation systems on Aneityum in Vanuatu refused to be impressed whoever had built them, commenting that there are:

aqueducts for the irrigation of plantations which, though extensive, come far short of that which now unites Glasgow and the Highland Lochs (1860).

The term 'irrigation' is often loosely applied and I will deal mainly with true irrigation, that is diversion of water from source to fields. Related techniques include the management by ditching of freshwater swamps, and the digging of pits to tap the water table beneath atolls and other low islands. True irrigation is associated in Melanesia almost exclusively with the growing of the root crop taro (Colocasia esculenta) and is found in parts of New Guinea, the Solomons, Vanuatu, New Caledonia and Fiji. Irrigation is practised in Melanesia under two conditions. Firstly in areas with significant dry seasons to create conditions allowing the growth of crops which require considerable amounts of water; secondly in areas where rainfall is usually sufficient to promote growth, 'supplemental' irrigation is used as a safeguard against occasional drought but more importantly to promote higher yields. This corresponds to Yen's inferred sequence. The former condition is equivalent to his formative adaptation dictated by natural climatic and edaphic factors, and the latter 'supplemental' conditions can be seen as examples of intensification, triggered by dynamic social environments. If we use Brookfield's (1972) division of agricultural production into subsistence, trade and social
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components then intensification, in this case by the expansion of irrigation, could be a response to the factors outlined by Yen in his paper: population pressure (however defined or perceived), the requirements of production for trade or for ceremonial purposes, competitive feasting, or class pressures in stratified societies.

The extent to which irrigation is mainly a response to natural climatic factors can be examined by comparing the distribution of true irrigation systems in Melanesia with that of mean annual rainfall and mean rainfall during each third of the year (data from Brookfield and Hart 1966 and for Papua New Guinea from McAlpine, Keig and Short 1975). In many cases irrigation is practised in areas with less than 2500 millimetres of yearly rainfall, and a marked dry season from about July to November, as pointed out by scholars from Rivers (1926), to Bellwood (1978:147) but this easy environmental generalization is by no means the full story.

In Papua New Guinea the supplemental aspect of irrigation is important certainly on Mussau Island, and in the Solomons it would appear to be important on New Georgia, Rendova and Kolombangara. On Anetiyum in Vanuatu are found some of the most highly developed irrigation systems in the Pacific, but climatic variables examined suggest that irrigation would only occasionally be necessary to ensure adequate crop growth over much of the island, a supplemental use as insurance against occasional drought. The scale and ubiquity of such systems there seems to relate more to the pre-missionization social system which involved competitive feasting between districts under different chiefs. The first missionary stationed there, John Geddie, in a letter published in the Missionary Register for January 1852, wrote:

Feasts are common, and in the estimation of the natives, are events of great importance .... One district gives a feast to another, and receives one in return - but the two parties do not eat together .... It is neither more nor less than an exchange of food. As the importance of a chief is judged of by the quantity of food collected on such occasions, the common people are most heavily taxed in order to support his dignity ... much that is collected spoils before it can be eaten.

In his journal of 14 July 1852 (Miller 1975:135) Geddie also mentions feasts, noting that 'Pigs, taro, bananas, sugarcane, coconuts, etc. were all tabued for this purpose', and again stresses 'there was such an abundance of food that much of it was wasted before it could be used'. This sort of behaviour was of course anathema to the dour Nova Scotian and Scottish Presbyterian missionaries, but goes some way to explaining the extreme development of irrigation systems on that island.

New Caledonia is a dry country and irrigation of taro is to be expected, but as noted by Curry (1962:51-52) it is found not only on the dry west coast, but also in the central mountain chain and the wetter east coast. On the east coast in the present commune of Canala were quite elaborate trade systems to exchange the irrigated taro of the inland clans with fish, turtles and crustacea caught by the coastal inhabitants (Doumenge 1965:64-65). At least in this area the stimulus of trade to the
expansion of irrigation systems seems important. Writing of Lakeba Island in Eastern Fiji, Muriel Brookfield (1979:134) points out that:

Despite their small area, the swamps and other wet areas are capable of yielding far more taro than is required by the resident population. This enables the Tui Nayau, other chiefs and islanders to extend hospitality to visitors, and to send food to other islands in time of need. Lakeba was traditionally regarded as the 'food larder' of central and southern Lau, and this is one reason for its pivotal place in the Lauan political system, and in linkages with Tonga and the Fiji island groups to north and west. The Lakeba wet lands are a resource envied by the people of other less-favoured islands.

In island Melanesia some of the most politically stratified societies of the recent past were found in New Caledonia, on Aneityum and in parts of Fiji, areas where irrigation was more highly developed than elsewhere. In Pacific stratified political systems, there is often a stress on feasting, food pretention and exchange, with chiefly power based in part on ritual control over agricultural production. An association with irrigated taro agriculture is perhaps thus not unexpected; given the high yields, all year round production (unlike seasonal yam and breadfruit crops), and the relative permanence of terrace and canal systems, irrigated taro where environmentally possible is clearly a very suitable crop to be at the basis of such societies (cf. Earle 1978:173).

There is thus no need to invoke Wittfogel's (1957) 'hydraulic hypothesis' of management requirements of irrigation systems necessitating a centralized despotic government; there is no mechanical link between technology and political power. Maurice Godelier has put the point well:

If modern anthropology has confirmed the argument that the relationship between the development of productive forces and the development of social inequalities is not mechanical, it has on the whole shown that social competition in class societies provides the major incentive to surplus production and, in the long term leads indirectly to progress in productive forces (1977:110-111).

In the areas of Melanesia where the presence of irrigation is not solely explained by climatic and edaphic conditions, it is precisely this incentive to surplus production which has led to the development of systems which, even if not on the scale of the aqueduct which united Glasgow and the highland lochs, so impressed most early European visitors.

I will now go into more detail about the techniques actually involved, and examine the causes for some of the variation in techniques found in Melanesia, some of the diversity behind the uniformity. Let us start at the water diversion point from the river or stream. Dams are usually of loose boulders so that surplus water can easily percolate through. Mud and brushwood can be used to make the dams less permeable in drier periods of reduced river flow. After heavy rain the water flows over the top of the
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dam or may even wash it away entirely. The dams are usually no more than one metre high to permit easy repair or reconstruction and are located where rivers are shallow even if wider at such points. Dams up to one hundred metres wide have been recorded in Milne Bay Province, Papua New Guinea. The impermanence of the dams is a safety feature to ensure that excess water does not damage the canal or cause damage to plants in the garden. Overflow devices along the canals are often a further safety measure.

Sometimes water is turned almost directly from a stream into the garden area, but often unlined (or stone lined) canals up to several kilometres in length are necessary. In parts of Melanesia canals are found up to five kilometres in length, with one exceptional example in New Caledonia twelve kilometres long.

Found in association with such canals or in place of them are pipelines of bamboo, pandanus, or tree fern which again may be some kilometres long. The advantages of pipelines are that seepage and evaporation losses can be avoided, the water is more easily controlled and a greater degree of flexibility in garden siting is possible. In addition weed growth, which is often a problem in unlined canals, is avoided. Such pipelines are however inevitably fragile and short-lived whereas the canals are a relatively permanent feature.

Methods of water application to the crops traditionally practised include simple flooding, flowing sheets of water on levelled surfaces ('paddies' or 'pondfields') and channels round the perimeter of rectangular beds (a variant of 'island bed' systems), and corrugation or furrow irrigation. In simple flooding water is led to the upper edge of the garden and then circulates down, usually with simple wood or stone barriers to slow down the flow. This acts to control erosion and trap sediment. In some cases rough 'terraces' are constructed directly in small stream beds. Simple flooding is essentially a highland Papua New Guinea practice being found in Enga, Madang, Western Highlands, Eastern Highlands and Morobe Provinces, and irrigated garden areas are generally small.

Pondfield systems, widespread in island Melanesia and Polynesia and similar in many ways to techniques found associated with wet rice in southeast Asia, have been reported in Papua New Guinea only from Mussau Island, but they are found also in the Solomons, Banks Islands, Northern Vanuatu, New Caledonia and Fiji. The planted area is an artificial pond through which water is kept constantly flowing.

The 'island bed' system consists of water led around the perimeter of usually rectangular beds and it resembles the 'island bed' systems found in swamplands. It is used along a thirty kilometre strip of coast in Milne Bay and is also found in New Caledonia and Fiji.

In corrugation or furrow irrigation water is applied to the ground in small, shallow furrows from which it soaks laterally through the soil wetting the area between the corrugations. I have only seen this system in use on Aneityum in Southern Vanuatu. Descriptions of irrigation practices in the Damal area and near Lake Sentani in West Papua, in West New Britain and Bougainville in Papua New Guinea and on Malekula in Vanuatu do not give information on methods of water application.
**Figure 1**

**True Irrigation Systems in Melanesia**

<table>
<thead>
<tr>
<th>Simple Flooding PNG -</th>
<th>Island Beds PNG -</th>
<th>Pondfields PNG -</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enga</td>
<td>Milne Bay</td>
<td>Mussau (New Ireland)</td>
</tr>
<tr>
<td>Madang</td>
<td></td>
<td></td>
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<tr>
<td>W. Highlands</td>
<td>New Caledonia</td>
<td></td>
</tr>
<tr>
<td>E. Highlands</td>
<td>Fiji</td>
<td></td>
</tr>
<tr>
<td>Morobe</td>
<td></td>
<td></td>
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<tr>
<td>Central (?)</td>
<td></td>
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</tr>
</tbody>
</table>

**Batiki**

**Kadavu**

**Lakeba**

**Moala**

*(and probably elsewhere)*

**Vanuatu -**

**Ureparapara**

**Motalava**

**Gaua**

**Vanua Lava**

**Espiritu Santo**

**N.W. Aoba**

**Maewo**

**Pentecost**

**Method Unclear**

**West Irian -**

**Damal area**

**Lake Sentani area**

**PNG -**

<table>
<thead>
<tr>
<th>East New Britain Bougainville (North Solomons)</th>
</tr>
</thead>
</table>

**Vanuatu -**

**Malekula**

**Fiji -**

**Koro**

**New Caledonia**

**Fiji -**

**Viti Levu**

**Vanua Levu**

**Kadavu**

**Lakeba (?)**

**Ovalau**

**Taveuni**

**Gau**

Full references will appear in 'Taro Irrigation in Melanesia: Descriptive Catalogue and Annotated Bibliography', Department of Prehistory, Research School of Pacific Studies (in preparation).
Yields of taro under these different irrigation techniques are generally much higher than under dryland conditions, although the number of yield figures collected are few and far between. For simple flooding systems in Papua New Guinea, yields from Awa groups (Eastern Highlands) are 18.4 to 21.8 mt/ha/yr (corms only) and at Patep (Morobe) 37.6 mt/ha (growth period unknown). Dryland taro yields at Patep were given as 12.5 mt/ha, while from elsewhere in Papua New Guinea and the Pacific, yields are from 2.5 mt to 15 mt/ha/yr, with sometimes exceptional yields of 30 mt being recorded for pure stands. From Fiji island bed figures recorded were 16.6 to 21.0 mt/ha/yr, and for pondfield systems in Vanuatu my own calculations suggest yields of 40-65 mt/ha/yr. Commercial Hawaiian farmers (mostly using fertilizers) obtain yields of 22-50 mt/ha/yr from pondfield systems.

We have examined the distribution of true irrigation in Melanesia in terms of climatic data, but how do we account for the distribution of the particular techniques of irrigation found in the region. One common sequence of techniques in Polynesia is a change over time in one plot from pondfield to island bed methods, followed by a fallow period and then a reactivation of the pondfield. This is one response to declining yields experienced because of soil exhaustion with continuous cultivation. Drying out the pondfield and then turning the soil over to form a raised bed or mound within the plot causes aerobic conditions allowing rapid decay of organic materials and thus increased nutrient availability (Earle 1978:117). One might expect to find permanent island bed systems in areas of poor soil fertility. In Milne Bay Province, Papua New Guinea, the soils of the coastal plain appear fairly poor and the short fallow period generally in use (only four years between taro plantings) exacerbates this (Kahn 1979). This necessitates turning over the soil of the island beds to maintain fertility. A pondfield regime here would perhaps not allow sustained production on these soils. In addition, the terrain on the plains may be unsuitable for pondfield agriculture. On near level ground, flow would be sluggish and water temperature would perhaps increase to levels where *Pythium* corm rot would occur (cf. Parris 1941). In New Caledonia and Fiji, island bed systems are found in valley bottoms or plains and appear to be a response to similar factors, especially in poorly drained areas where periodic draining and aeration of the soil is not possible.

Simple flooding is very much a New Guinea highlands phenomenon. It is the least intensive of the irrigation techniques and would seem to reflect four hundred and fifty years. Evidence from the highland valley floors shows periods of intensive use starting at least six thousand years ago with wet taro as a probable staple grown in the swamps. These alternate with periods of abandonment, in explanation of which Golson (1977) has suggested a series of technological innovations allowing more intensive use of dryland gardens, such as tillage, *Casuarina* fallow and finally the sweet potato. For at least the final period of abandonment prior to European contact Gorecki (1979b) has suggested the abandonment not only of swampland agriculture but of habitation on the valley floor at large, due to fear of sickness. He further suggests that this may have been a factor in abandonments prior to the final one. If this were so, when people left the valley floors for higher altitudes they may have tried to recreate land suitable for the cultivation of wet taro in primary forest and hillslope environments. Thus hillslope irrigation of taro could have been a more important and widespread component of highlands agricultural systems before
the introduction of sweet potato (Gorecki 1979a:119). Simple flooding may thus be a highlands innovation albeit an ancient one. It is only found within the area of the Trans-New Guinea Phylum of Papuan languages, and an antiquity of more than six thousand years is possible (cf. Gorecki 1979b). On this basis it could be predicted that irrigation techniques in the Damal area of the West Irian highlands (Ellenberger 1962) and perhaps also those reported from near Lake Sentani (Moolenburgh 1904:180) would be of the simple flooding type.

Corrugation or furrow irrigation has been reported only from Aneityum in Vanuatu (see Spriggs 1980, for photograph) and would seem to be a local adaptation. The soils on Aneityum are generally of very poor fertility and unstable and thus prone to erosion. Modern furrow irrigation is generally used in areas where the land surface is moderately steep and irregular, and on fine-textured soils. It ensures uniform wetting and limits erosion on steep lands (Cantor 1967:33).

This leaves us with pondfield techniques, whose distribution reveals some suggestive patterns when compared to linguistic groupings. It has already been noted that simple flooding techniques are found only among speakers of languages within the Trans-New Guinea Phylum of Papuan languages. There is an equally strong association of pondfield irrigation with the distribution of Oceanic Austronesian languages. There is a total absence of pondfield irrigation techniques from the island of New Guinea and other parts of Melanesia where non-Oceanic languages are spoken. There is in particular a significant relation between pondfield irrigation and areas where the East Oceanic languages, forming a major sub-group within Oceanic, are spoken. These areas are Polynesia, Fiji, North and Central Vanuatu, Nuclear Micronesia and possibly the southeast Solomons.

As already mentioned, pondfield systems are widespread in Polynesia and Fiji. In Vanuatu they occur only in areas of one out of six sub-groups of the Vanuatu languages, Central and North Vanuatan, and this is the one sub-group that is within East Oceanic (Tryon 1977, and this volume). Thus, while pondfields are common in West and Central Santo, they are not found in East Santo, the languages of which are not East Oceanic. From the southeast Solomons we have the report of the Spanish explorers of pondfields from Guadalcanal, possibly an East Oceanic area. In Micronesia, pondfield taro systems are known from Ponape in the Eastern Carolines (Ayers 1978; Ayres et al. 1979:110), again an East Oceanic area and also from Palau (McKnight and Obak 1960). Palauan is a non-Oceanic Austronesian sub-family, more related to northeast Indonesian and Philippine languages. The association of pondfields with Eastern Oceanic languages in Melanesia is complicated by the presence of pondfield systems in New Caledonia, on New Georgia, Rendova and Kolombangara in the Solomons, and on Mussau north of New Ireland, all areas of different Oceanic language sub-groups.

The majority of linguists see the Oceanic languages as being descended from a single ancestral language community which entered northwest Melanesia from eastern Indonesia (Pawley and Green 1973, but see Tryon, this conference) and so perhaps the origins of pondfield irrigation in the Pacific lie in island Southeast Asia. Yen (1973a:83) has previously suggested that the Melanesia-Polynesia border region was a centre for the development of irrigation technology independent of Southeast Asian developments. This suggestion was based on the supposed lack of irrigation
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from the New Guinea area but the distribution of methods of true irrigation are now seen to be much wider than Yen had supposed. Certain irrigation techniques may well have developed independently in New Guinea or island Melanesia, but the similarity in pondfield morphology and techniques between Oceania and island Southeast Asia suggests a common origin.

In Southeast Asia, pondfield systems are most commonly used for the growing of rice but there are examples of taro being grown in pondfields either as an intercrop with rice or as a monocrop. In Southwest Sulawesi pondfields planted solely to taro are found among the ricefields (Ian Glover, personal communication). In the northern Philippines taro is sometimes intercropped with rice in the pondfields or planted on its own in small flooded plots (Conklin 1974; 1980). Taro is also planted in pondfields in Java (Ochse 1977:55) while on Botel Tobago, an island between the Philippines and Taiwan, large-scale pondfield systems are found and rice is absent (Kano and Segawa 1956). Pondfield systems for taro probably also occur elsewhere in island Southeast Asia.

If one were to postulate a movement of pondfield users from the Philippines/Indonesia area, through the Solomons, Northern Vanuatu, Fiji and into Polynesia one would have to ask why the plant involved was taro and not rice. The most parsimonious explanation would be that rice as a crop in pondfields in the Philippines/Indonesian area is a late development postdating the presumed dispersal of Oceanic speakers about five thousand years ago (Pawley and Green 1973; Tryon, this volume) (cf. the discussion in Chang 1970:183). Rice may well have replaced taro as a staple there because of ease of storage and transport, making it a convenient form of tribute in expanding polities. Taro does not generally store for any length of time once it has been harvested. Godelier (1977:194) has noted just such a situation in South America where in its conquered territories the Inca State encouraged an expansion of maize agriculture for tribute rather than the traditional tuber staples. Maize, like rice, is a plant easily stored and transported.

All of these linguistic (and by extension cultural) correlations are perhaps far-fetched and on a level with Riesenfeld's Megalithic Cultures of Melanesia (1951) or even perhaps hark back to Perry's Children of the Sun (1923) and other extreme diffusionist extravaganzas. They will remain so unless direct dating evidence from archaeological investigations is forthcoming. At present such evidence is sparse. One problem is that once pondfield or island bed systems are constructed they are usually permanent features unless buried in landslides or by flood deposition. The soil in them is constantly being turned over and mixed and although charcoal for radiocarbon dating can be found in them, the material which is dated will often only belong to the latest period of use. Simple flooding techniques, with their minimal alteration of soil or slope and often fed by bamboo pipelines, may well be archaeologically invisible and therefore of course undatable.

The use of swamplands for agriculture in the New Guinea highlands has been dated to nine thousand years ago, or more certainly six thousand years ago, when the swampland equivalents of island bed systems were in use (Golson 1977). Archaeologists have until recently tended to ignore agricultural remains, partly because of a focus on obtaining basic artefactual sequences and partly because of a lack of suitable
methodologies for examining such remains. This is now changing, much of
the initial work being done in Polynesia. In various locations in Hawaii
pondfield systems have been found buried by alluvial deposits. The
earliest are dated to about seven hundred years ago (Green 1980) but this
is unlikely to date the initial use of irrigation systems in those islands.
Kirch (1975 and 1976) examined buried pondfield systems on East Futuna
(Hoorn and Wallis Islands) and suggests an association of pondfield
agriculture with the earliest Lapita settlers in the latter half of the
first millenium BC on the basis of site location in relation to early
occupation sites. Direct dating evidence, however only exists for the last
four hundred or so years. On Kolombangara in the Solomons, Yen (1973b:40)
obtained a date of AD1720 ± 90 years for what was judged as close to the
early level of agricultural use of one pondfield terrace. On Anetium
there are considerable problems in locating early sites. The northern
coastal plain where many of the largest irrigation systems were located is
a very recent product of man-induced erosion of the hillsides and so early
systems may be very deeply buried. Thus we have no firm dates for
irrigation there more than a few hundred years old. As far as I am aware,
no attempts have yet been made to date canal-fed systems in Fiji, New
Caledonia or New Guinea.

It is perhaps time to abandon speculation and move on from examining
why they were where they were, when they were there, and where they were
before they were there, to consider why they aren't there anymore.

We have seen that highly productive traditional irrigation
technologies have been used in the past in Melanesia and yet in many areas
there has been a marked decline or even total cessation of these very
productive strategies over the last hundred years. The reasons are many
but include substantial population decline through European diseases, and
more recently, local population disruptions because of migration to urban
areas or to work on plantations. The general change in the region to an
increasing reliance on cash crops such as coconuts, cocoa, tea, etc., has
competed directly with traditional agricultural pursuits for land and
labour. In some areas alienation or outright seizure of land by European
interests has been important. The breakdown or transformation of
traditional patterns of leadership, which may have had a role in the
organization of intensive agricultural systems may also have been
important. In Papua New Guinea and the Solomon Islands in particular taro
disease problems have been significant.

Do these traditional systems of management and manipulation of
freshwater resources have a future in Melanesia and the Pacific? Agronomists in the Pacific region have been lamentably slow to realize the
extent of such systems or the fund of technical expertise and environmental
knowledge embodied in their operation, as I have pointed out elsewhere
(Spriggs 1980). The need for basic agronomic research on traditional
water-aided agricultural systems in Melanesia cannot be overstressed.
Irrigation to alleviate seasonal crop shortfall could be a partial solution
to some of the food problems experienced in Melanesia and it is likely that
traditional techniques adapted to the region and conceived at an
appropriate level of technology will be more useful than any imported
technologies might be.
There are encouraging signs that in some areas of the Pacific traditional irrigation and wetland agricultural techniques are picking up again. On Kolombangara in the Solomon Islands, pondfield systems unused since World War II are being brought back into commission (Miller 1979:148). In the Cook Islands there are plans to encourage greater production of wet taro for export to New Zealand. I will give an example of this kind of project which may have wider relevance. It comes from my work for the Vanuatu Department of Agriculture on Aneityum Island where an aid project has recently been started to encourage the growing of wet taro for supplying urban and possibly export markets using traditional methods such as canal-fed corrugation irrigation and swampland island bed systems.

In 1978 and 1979 I was engaged in field research examining prehistoric remains and traditional irrigation technologies on Aneityum. As I have already mentioned the island is covered with the remains of ancient irrigation and wetland systems in the form of a permanent infrastructure of stone-faced terraces, canals, and ditched swamps (Spriggs 1979 and 1980). The techniques were only known to the older inhabitants of the island, and although several swampland systems were in use in 1979 only one very small canal-fed system was in operation and so there was a very real danger of these highly productive techniques being lost. Following European contact the population was decimated by disease and the population decreased from nearly 4000 people in 1854 (after two previous epidemics of unknown mortality) to below 200 people by the late 1930s. The population has risen since this low point and now stands at about 460 people. The aim of the pilot project is to give the initial 'push' to the development of taro as a cash crop and to ensure that the younger generation has a chance to learn the traditional techniques for its production. Project funding is available for two years to provide money for paying people to undertake the major initial tasks such as dam and canal reconstruction, forest clearance and the cleaning of swamp ditches. Tools such as crowbars, spades, forks, pickaxes, etc., have been provided and the Government has undertaken to arrange the marketing of the taro. Why do people need this initial 'push' and cash incentive? One important reason is the decline in the power of the chiefs as organizers of the labour force. They can no longer command people to turn out for communal labour as in the past. Although the people are genuinely interested in growing taro as a cash crop, they would not invest time and effort in such labour-intensive tasks as digging canals for two main reasons: firstly most people on the island had never made the canals before and were sceptical that they could complete the task. When paid, they would at least attempt the task and thus realized the comparative ease with which such work could be accomplished. Secondly, without help in finding a market they felt that any taro they produced they would not be able to sell a market for. There was thus a vicious circle to be broken. Many people had no faith that the canals could be brought back to operation, and the chiefs and old men who had made such canals in the past no longer had the power to coerce the community to help them in redigging them. Paying for the initial heavy reconstruction tasks has broken this circle. The people do not have the required expertise in negotiating for buyers and ships to transport their produce, hence, they were discouraged from planting. On the other hand commercial buyers could see no evidence that sufficient quantities of taro were being or could be produced and so had not come forward to negotiate for the purchase of taro that had not yet been planted. Government help in their field has again been crucial in getting the project going.
The project was only initiated in August 1980 and so comments on its degree of success are perhaps premature. At the first of the three population centres on the island work started immediately, and regularly over thirty men, women and children turned out every day to work. A canal over half a kilometre long was repaired, and the first fifty metres of its course and the take-off dam were rebuilt, having been completely washed away. There is no-one now living who has ever seen this particular canal-fed system in use, and it has lain dormant for the last one hundred years. Under the dense forest however the subsidiary stone-lined channels, terraces and beds remained. A large area of forest was cut and will be left to dry for a few months before being burnt off and planted.

In the same area, directly behind the main village, is a large swamp behind a sandbar of consolidated beach rock. This was never traditionally used to grow taro because there was no outflow and so the water level in the swamp could not be regulated. Just before World War II a timber company then operating on the island employed the people (using metal tools) to cut a channel through the sandbar and dig drainage channels within the swamp for controlling mosquitoes. Since that time the drains have been allowed to silt up. Areas on the edge of the swamp have been used since then to grow taro; results are encouraging, but the uncontrolled water levels have prevented extension of planting into the middle of the swamp. As part of the aid project, money was provided to clear the swamp channels and outflow and to plant experimentally some island beds in the middle of the swamp to assess whether the whole swamp (over five hectares in extent) can be brought into production. Traditional techniques (albeit with metal tools) have been used throughout as well as community organized labour, representing an extension to a new location of traditional swamp management practices. Elsewhere on the island, other previously ditched swamps and former canal-fed systems are also being brought back into production. The return for labour appears very good and I see no reason why in such circumstances traditional techniques and traditional organization at the village level cannot be utilized successfully in cash cropping.

In the past, government agricultural officers have almost completely ignored these highly productive agricultural techniques. There is a degree of ethnocentric bias and paternalism involved here, a view that 'development' is something people undergo in a passive manner, something they accede to, a package they are handed rather than a process which their own traditional knowledge and expertise can inform. One reason for the great danger we face that this expertise may soon become lost, is precisely because governments have consistently undervalued and ignored this traditional knowledge with the result that the people themselves have come to undervalue it as well, and have come to believe in their passive role. It is perhaps not they but the agricultural officers and planners who need to adopt a more humble and unaccustomed role, and learn from this expertise. They will then find out, as pointed out to me by a very old Aneityumese man when water started to flow again along an old canal never used even in his lifetime, 'those old fellahs knew a thing or two'.
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